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THE MANUFACTURE

OF

IRON AND STEEL TUBES.

BY

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"*Notes on the Construction of Cranes and Lifting Machinery,*" "*The Evolution of Modern Small Arms and Ammunition,*" "*Mechanical Engineering Materials,*" "*Notes on the Construction and Working of Pumps.*"

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PREFACE TO SECOND EDITION.

THIS edition contains the whole of the original matter, with the necessary revision respecting the present condition of the various patents referred to.

The eighth and succeeding chapters contain additional general particulars relating to the manufacture of iron and steel tubes, and refer specifically to pertinent British patent specifications published between the former and the present edition of this little work.

The List of Patents given as an appendix has been thoroughly revised and brought up to date. Though not completely exhaustive, the author believes that it will be found useful to manufacturers and others as affording a ready and convenient key to the "state of the art" in the various branches of this industry.

E. C. R. M.

13, Temple Street, Birmingham,
July, 1903.

PREFACE TO FIRST EDITION.

THE series of articles herewith presented in book form comprise a development of a special course of lectures delivered by the author during the last session of the Birmingham Municipal Technical School.

As a summary of the past efforts and achievements of inventors, based on their patent specifications, the author trusts that the work will prove of some practical utility to manufacturers and others interested in iron and steel tubes.

E. C. R. M.

13, Temple Street, Birmingham,
July, 1897.

CONTENTS.

THE MANUFACTURE

OF

IRON AND STEEL TUBES.

CHAPTER I.—INTRODUCTION.

A TUBE has been defined as "anything hollow or concave, with some degree of length." Such a definition has certainly the merit of comprehensiveness, for, as one critic observes, it will include "a railway tunnel or a coffee pot, a decayed tooth or a drain pipe." Although the title of the series of articles commencing herewith will be sufficient by its limitation of the material of construction to prevent any such hopeless confusion in the minds of our readers, yet we have no intention of attempting to treat of iron and steel tubes of any and every form, but shall confine ourselves chiefly to butt and lap welded tubes of iron, open or close jointed and consolidated tubes, and processes and appliances for the production of weldless or seamless steel tubing for various purposes.

The articles are based upon the printed patent specifications relating to this subject, and the illustrations are prepared from the drawings attached to such specifications. To enable the reader to make a closer study of any of the specifications referred to, the official number and date of each will be given, and as far as possible the lapsing of such patents as have been granted during the past fourteen years through the non-payment of renewal fees will be recorded.

THE MANUFACTURE OF GUN BARRELS FROM WROUGHT-IRON STRIP.

Probably the manufacture of barrels for firearms constitutes the earliest application of wrought-iron tubes. Such an industry would find employment for many smiths in the time when the only known method of production consisted in the bending of an iron plate or strip to form a "skelp," the edges of which were welded together piecemeal by hammering, the internal support during the welding being provided by the insertion of a rod or mandrel.

In the year 1812, Henry Osborn, of Birmingham, obtained letters patent for his invention, described in specification No. 3617, of 1812, "for machinery for welding and making

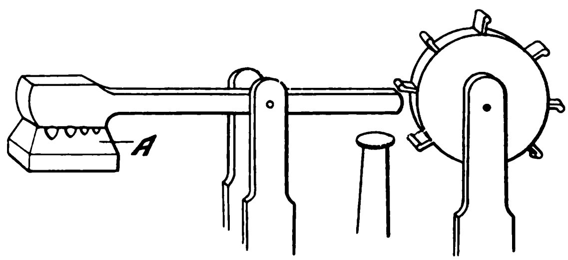


FIG. 1.

barrels of firearms and other cylindrical articles." The specification is accompanied by a sheet of drawings giving illustrations of the improved machinery, such as shown by the adjoining figs. 1 and 2 herewith. Referring to fig. 1, the skelp is raised to a welding heat in an open or a close fire, and after the mandrel has been inserted is then placed in the swage or anvil A, and welded by the action of the tilt hammer. In the words of the specification, "the different grooves in the swage assist in gathering the different parts of the barrel or cylinder in the process of welding."

Referring to fig. 2, the inventor states: "I take a skelp, place it in either of the beds 1, 2, 3, according to the required to be welded, and which welding is effected

by the swage segments A performing half a revolution, the manner of which is explained by the profile B."

In the following year, 1813, the same inventor, Henry Osborn, obtained letters patent for "machinery for tapering gun barrels, &c.," which he describes in his specification No. 3740, of 1813. The tapering is effected by passing the tube through grooved rolls.

Gas Tubes.

In the early days of gas lighting, gun barrels were employed for the conveyance of the gas. In 1815, William Murdoch, the founder of gas lighting, in setting down a gas installation at the Soho Works, near Birmingham, employed old musket barrels screwed together as the means for conveying the gas throughout the works. The close of the long European war had thrown an abundance of such barrels on the market, and hence they were undoubtedly

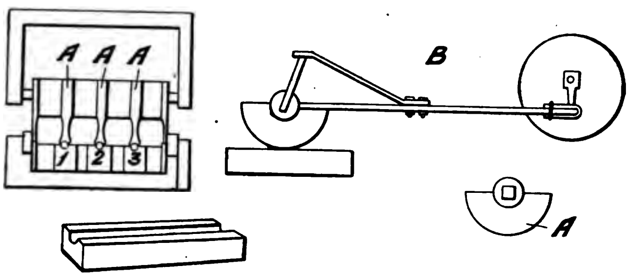


Fig. 2.

the most economical form of tubing available for the purpose. Some one has been unkind enough to observe that in modern times Murdoch's plan has been reversed, for instead of making gas pipes from gun barrels, it is said that gun barrels for the African and other remote markets are sometimes made from gas pipes.

The extension of gas lighting called for the production of iron tubes with greater facility and at less cost than by the methods employed for gun barrel making, and inventors were equal to the occasion. In the year 1824, James Russell,

of Wednesbury, filed a specification, No. 4892, setting forth "an improvement in the manufacture of tubes for gas and other purposes." The adjoining fig. 3 represents the apparatus employed for welding. The tilt hammer is

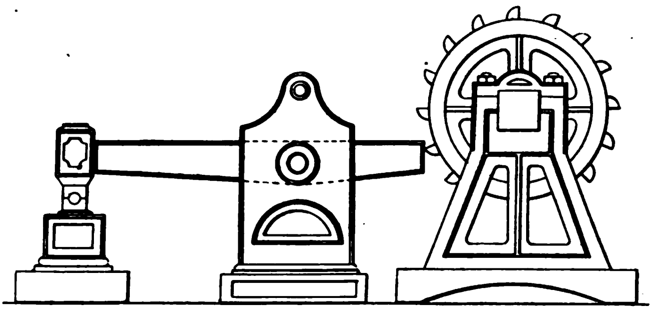


FIG. 3.

retained, but the weld can be formed either with or without a mandrel, the edges being butted against each other, not overlapped as in gun-barrel welding. The tube is finished between rolls in conjunction with a mandrel, as

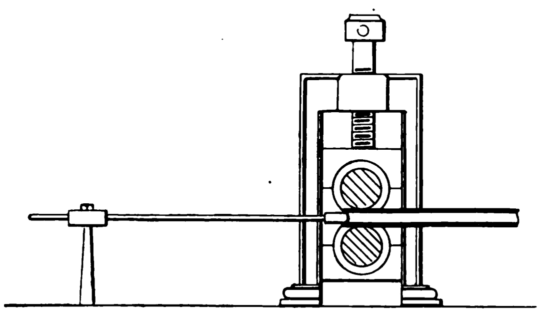


FIG. 4.

shown at figs 4 and 5. The importance of this specification is in the disclosure that a sufficiently sound weld can be made by pressing or forcing the abutting edges of the tube against each other. With this method of welding no

allowance is necessary in the width of the strip employed for the overlapping of the edges, as with lap-welding processes.

In 1825, Cornelius Whitehouse, of Wednesbury, invented the process of butt-welding wrought-iron tubes, which is still employed in all such tube manufactories at the present day. The process is described in the specification, No. 5109 of 1825, under the title of "Certain improvements in manufacturing tubes for gas and other purposes." The apparatus, as described by the inventor, is shown in the adjoining figs. 6, 7, 8, and 9. The tilt hammer is entirely

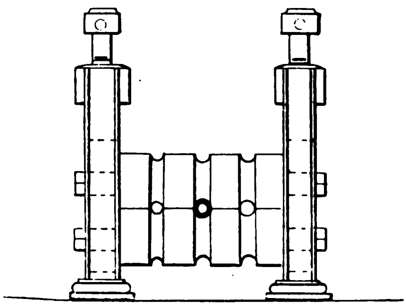


FIG. 5.

dispensed with, also the rolls and mandrel of the aforementioned specification. The inventor describes his process as follows: "I prepare a piece of flat iron, commonly called plough-plate iron, of a suitable substance and width, according to the intended calibre of the tube. This piece of flat iron is prepared for welding by being bent up on the sides, or, as it is commonly termed, turned over, the edges meeting, or nearly so, and the piece assuming the form of a long cylindrical tube. This tube is then put into a hollow fire, heated by a blast, and when the iron is upon the point of fusion it is to be drawn out of the furnace by means of a chain attached to a draw bench, and passed through a pair of dies of the size required, by which means the edges of the iron will become welded together. The apparatus which I employ for this purpose is shown at fig. 6, which is a side view of

the furnace A, and of the draw bench B, with its spur wheel C, which may be put in operation by a hand winch, or by attaching its axle to the moving part of a steam engine. D is a screw press, in which the dies are placed for swaging and uniting the edges of the iron tube E as it passes through. A front view of this screw press is shown at fig. 7, and one

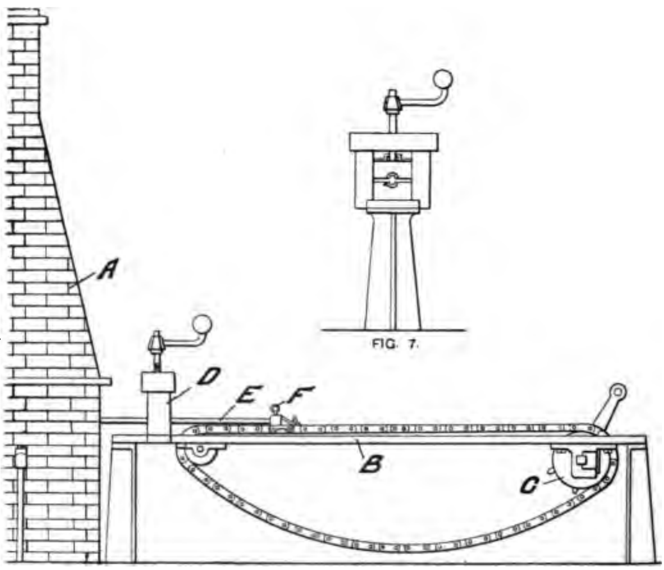


FIG. 7.

FIG. 6.

of the dies removed from the press is shown at fig. 8. The iron tube E, having been heated to the point of fusion in the furnace A, is drawn out by the chain of the draw bench, and the screw of the press D being turned so as to bring the dies to their proper point of bearing, the two edges of the iron become pressed together, and a perfect welding of the tube is effected. The screw clamp or other fastening F, by which the end of the tube is held and attached to the chain, is now opened, and the tube removed. The reverse side of the tube

is then grasped by it, and that part which has not been welded is introduced into the furnace, and after being heated is drawn through the dies and welded in the manner above described. The process of welding these tubes may be performed without the screw press and dies above described. A pair of pincers, as shown at fig. 9, may be employed instead, having a hole for the tube to pass through similar to the dies. One arm and chap of these pincers is shown in section at the lower part of fig. 9, for the purpose of exhibiting the conical figure of the hole which the tube E is to pass through as it is drawn out of the furnace by the chain of the draw bench. A workman brings the pincers against the

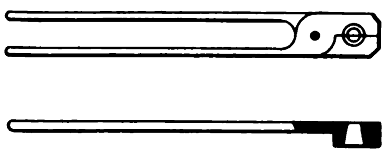


FIG. 9.

FIG. 8.

standard at a steadying place, and as the tube passes through the hole of the pincers the welding of the edges of the iron is effected."

"I have thus described the modes which I have employed and found fully to answer the purpose in welding tubes of iron, but I do not confine myself to the employment of this precise construction of apparatus, as several variations may be made without deviating from the principles of my invention, which is to heat the previously prepared tubes of iron to a welding heat—that is, nearly to the point of fusion, and then, after withdrawing them from the fire, to pass them between dies, or through holes, by which the edges of the heated iron may be pressed together and the joint firmly welded. The advantages of this tube compared with those made in the ordinary way are these: The iron is [illegible] improved by the operation of the [illegible] generally diffused. The length of the pieces of iron thus made is likewise a great advantage, as [illegible] may be made from 2 ft. to [illegible] ft. long [illegible]

by the old modes the lengths of tubes cannot exceed 4 ft. without considerable difficulty, and, consequently, an increased expense. These tubes are likewise capable of resisting greater pressure from the uniformity of the heat throughout at which they have been welded; and, lastly, both their internal and external surfaces are rendered smooth, and greatly resembling drawn lead pipes."

The introduction of Whitehouse's invention at once greatly reduced the selling price of gas pipes. It is stated that the sum actually paid for welding a gas tube under the old gun-barrel principle was equal to the amount at which the complete and vastly superior tube was sold when made under the new process. Such process as described in Whitehouse's specification, and which we have inserted in full, may be seen in operation in any of the tube works in and around Birmingham, and elsewhere. Whitehouse, who is described as a whitesmith, assigned his patent to James Russell, of Wednesbury, on the condition that he was to be found employment by the said James Russell, and be paid an annuity of £50 during the term of the patent. The expense of obtaining the letters patent (which in those days amounted to about £125) was borne by James Russell.

With an invention of such importance it is not surprising to find that the patent granted thereon became the subject of much litigation, but it was held in the law courts that the method of welding tubes by circumferential pressure invented by Whitehouse was perfectly good subject matter for letters patent, which were accordingly upheld.

As the end of the fourteen years' term of the patent approached, the assignee considered that, owing to the vexatious law suits in which he had been involved, the amount of profit received was disproportionate to the merit of the invention. He was successful in obtaining an extension of the patent for a period of six years on the condition that he paid a royalty of £600 per annum to Cornelius Whitehouse, the inventor, during such extended period. The extended period expired, rendering the invention open to all makers and users, on February 26th, 1845.

CHAPTER II.

Steam Tubes and Patents Relating Thereto.

The production of steam tubes by the welding of the overlapping edges of wrought-iron skelps, in machines having rolls in conjunction with a stationary mandrel, appears a very simple operation in a well-organised tube works, but the process was only established after much costly experimenting. The production of gas pipes or tubes by the Whitehouse process, described in our previous chapter, had been well established when the success of George Stephenson's "Rocket," in 1829, created a demand for a larger and stronger form of tube than could be produced by butt welding.

An Englishman, Martin Jones, appears to have been one of the earliest of the workers who devoted themselves to the production of steam tubes in large quantities, but his labours, unlike the case of Cornelius Whitehouse with the butt-welding process, brought him nothing but disappointment and ruin. In a little book on "Wednesbury Workshops," by Mr. T. W. Hackwood, we read that Martin Jones, when in France, became connected with experiments in the production of machines for rolling solid wrought-iron cannon shot. The experiments were unsuccessful, but, as a result of the experience gained in conducting them, Jones conceived the idea of rolling wrought-iron tubes. He returned to England, and took part in some works at Birmingham, and after much experimenting, at his own cost, produced machines which, although far from perfect, contained the elements of eventual success. But having by this time exhausted his own and his wife's fortune, and being much pressed by his creditors, Jones placed his invention in the hands of a friend and neighbour, who lost no time in appropriating the matter entirely to himself, continued the experiments, and eventually obtained letters patent in his own name. This patentee and pirate of Jones's invention made over his patent rights to two Birmingham men of

large means—Ledsam and Bowers—and is said to have received from them royalties amounting to £30,000 per annum. We gather, however, that he was not particularly happy, for we read of his despatching himself by means of a razor, on a certain bright summer's morning.

At about the same time, the Messrs. Russell, of Wednesbury, had succeeded in making wrought-iron tubes with two rollers instead of with the four employed by Ledsam and Bowers, but the latter firm declared the Russell process to be an infringement of their patent. After much litigation, involving, it is recorded, an expenditure of £70,000, judgment was given in favour of the Russells, who were thus allowed to pursue their process of manufacture.

Adverting again to the published patent specifications, we find that on March 27th, 1840, Richard Prosser, of Birmingham, applied for letters patent for "Certain improvements in machinery or apparatus for manufacturing pipes." The official number of his specification is 8454, of 1840. The inventor says, in this specification: "My improvements relate to that kind of machinery or apparatus for manufacturing pipes of metal which operates by means of a pair of revolving rollers—that is, two such rollers having concave grooves around their circumferences, and the said groove around one roller corresponding to that around the other roller." We further read that "the mode of manufacturing pipes of metal by rolling between grooved rolls was, as regards lead pipes, invented by Mr. Wilkinson in 1790, and as regards pipes which are made from wrought-iron strip by Henry Osborn, in 1817. But whereas by such machinery or apparatus only one pair of revolving grooved rollers is used, one disposed above the other, to roll the metal between them, it follows that the compression which can be thereby exerted upon the metal of the pipe at each time of rolling it must be chiefly operative at the upper and lower sides only."

The skelps, after heating in a reverberatory or other furnace, are passed through a machine, having four grooved disc rollers driven at a uniform speed. The central space between the rolls regulates the external diameter of the tube, and the mandrel the internal diameter. Tubes of

other than circular form may be produced by suitably shaping the mandrel and the grooves in the rolls. The action of the machine is very rapid, only two seconds of time being required for the passage through and welding of each tube.

On July 24th, 1844, a specification, No. 10272, was filed by John James Russell and Thomas Henry Russell, describing the welding of a lap-jointed tube in a machine having a grooved travelling bed for the reception of the skelp, which it moves in alternate directions beneath a grooved welding roller, the internal support being provided by a mandrel. The to-and-fro movement of the bed or carriage is effected by means of a coarse pitched screw, which is driven by reversing gear.

In specification No. 9287, of 1842, in the names of Thomas Henry Russell and Cornelius Whitehouse, there is described a method of providing an internal support to tubes welded by drawing through dies. The applicants state that their invention "relates to improvements in welding the joints or seams of tubes when made by external pressure, by passing the iron in a welding state between dies or through holes; and the improvements consist of a means of employing internal support, and in such a manner that the instrument which gives the internal support being introduced into a partly formed tube through the dies or holes used, by which the requisite external pressure is obtained; and when the weld is completed, the instrument used for giving external support, owing to its being of small diameter when compared with the diameter of the finished tube, may readily be withdrawn by causing the welded tube to be pressed into a cylindrical form." Referring to the illustrations, fig. 10, the iron skelp of the section shown at A is drawn through the tongs B to a shape such as shown at C. A hollow bar or tube D is then placed in the interior of the skelp to form the internal support. The inventors state that their invention is "particularly applicable when thin welded iron tubes are desired, such as for the tubular flues of locomotive or similar boilers, for which purpose we are now using iron of No. 14 of the wire gauge, and we are now making such tubes from 1½ in. to 2 in. diameter, but those dimensions may be varied."

There are a large number of specifications relating t production of wrought-iron tubes to which we cannot

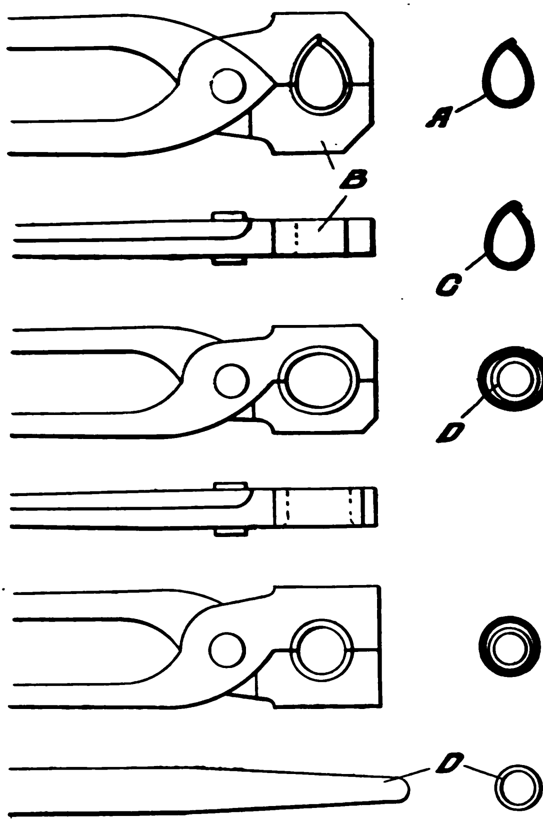


FIG. 10.

in detail, but of which a list will be subsequently compiled for reference.

Before passing from wrought-iron welded tubing we may note the improvements relating to the bevelling of the edges

of the tube strip for lap-welded tubes described by David Muckley, of Wednesbury, in his specification No. 3706, of 1891. In his specification this inventor states: "In the manufacture of lap-welded tubes according to the present mode of manufacture the two edges of the plates or strips

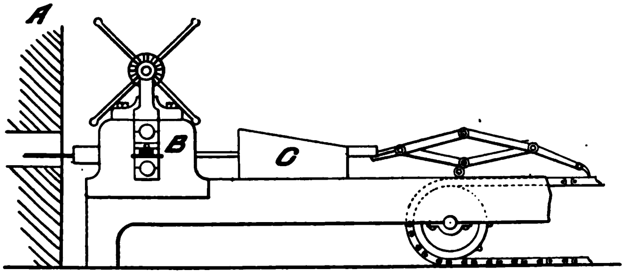


FIG. 11.

of metal are bevelled upon a bevelling table or what is the equivalent of a planing machine, and this forms a distinct and separate part of the process of making tubes. I avoid the necessity of so bevelling the edges by a cutting tool, and save the metal that would thus be cut away. That is to

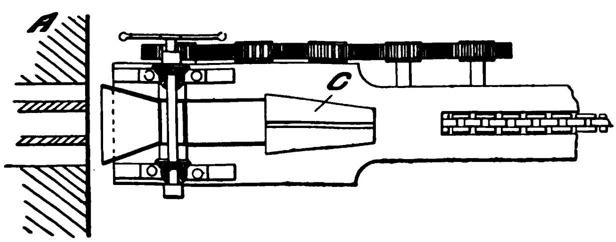


FIG. 12.

say, that by my mode I make a 12 in. strip equal to, say, 12¼ in. strip, or, on the other hand, I may economise this metal in adding to the length of the strip, thus effecting a considerable percentage of saving in the metal as well as the time taken up by the separate machine for bevelling the strips." The apparatus employed by Muckley is shown

in the adjoining figs. 11 to 16 inclusive. In front of the furnace A he places a pair of rolls, one of which is provided with bevelled edges, or one edge of each roll being bevelled. From the rolls the hot strip is drawn through the skelp

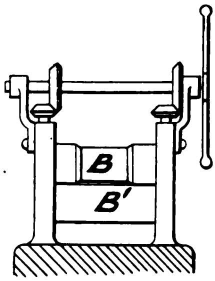


FIG. 13.

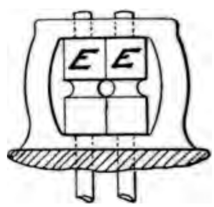


FIG. 14.

die C, or instead of such die the rolls E, fig. 14, may be employed. This patent was allowed to lapse in the year 1900.

We may also note the specification of Henry Howard, No. 5641, of 1890, describing an invention having for its object to expedite and simplify the welding process, whether

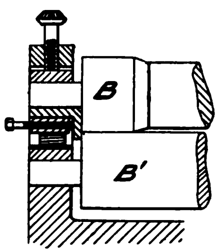


FIG. 15.

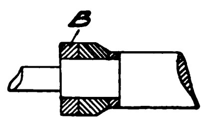


FIG. 16.

butt or lap. For this purpose the welding process was made to immediately follow the skelp-forming process in the manner illustrated at figs. 17, 18, and 19. Between the skelp former B, adjoining the furnace A, fig. 17, and the welding bell or tongs C, is a blow-pipe apparatus D for delivering a

sheet of flame upon the open unjointed edges of the skelp, for raising them to a welding heat. At fig. 18 the blow-pipe

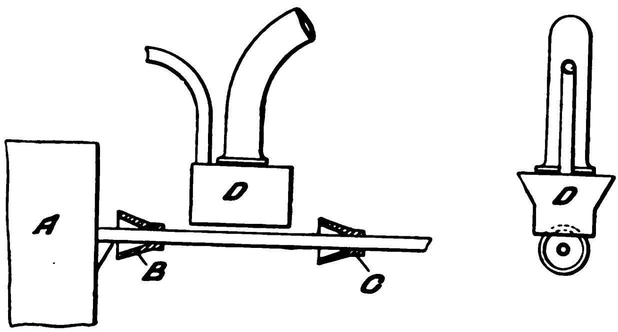


FIG. 17.

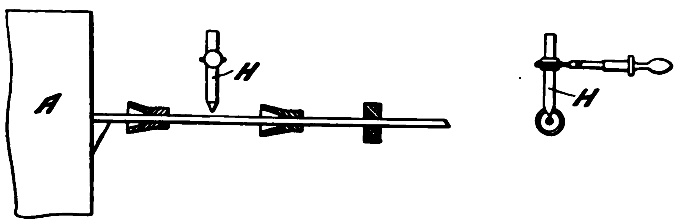


FIG. 18.

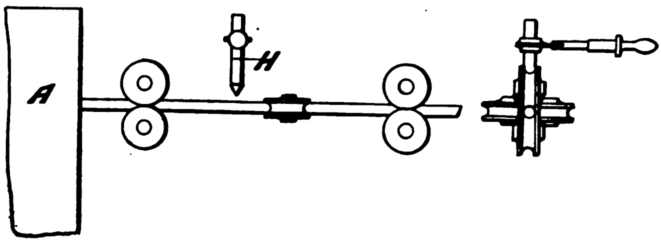


FIG. 19.

apparatus is displaced by the carbon rod H, constituting one of the electrodes of a voltaic arc, the edges of the skelp

forming the other electrode. At fig. 19 is represented the voltaic arc arrangement in combination with rolls employed for shaping the skelp, welding its edges, and perfecting the welded tube. The patent granted on this application has been allowed to lapse through the non-payment of renewal fees.

CHAPTER III.

Open or Close Jointed Tubes.

The tubes employed in the construction of bedsteads and for other similar purposes not having to resist either an external or internal liquid or gaseous pressure, as in the case of steam, water, and gas pipes, do not require the edges of the strip from which they are formed securely welding together, but such edges may be simply butted, making what is termed an open or close jointed tube.

The accompanying illustrations, figs. 21, 22, and 23, are from the specification No. 6262, of 1886, of Frederick Huggins, of the Britannia Tube Works, Birmingham, for "New or improved machinery for the manufacture of iron and steel tubes." The inventor states that his machinery is suitable for the manufacture of iron and steel tubes, whether welded or open or close jointed. It consists essentially of two pairs of rolls and a die having a trumpet-shaped axial opening in it. The said pairs of rolls turn on horizontal shafts working in bearings on the frame of the machine. The rolls at the front of the machine—that is, at that part at which enters the strip of iron or steel from which the tube is to be made—are of a shape suited to bend the strip passed between them into a trough shape—that is, semi-tubular, or nearly semi-tubular—one of the said rolls having a groove semi-circular in cross-section, and the other having a projection or flange semi-circular in cross-section, the said flange on one roll working in the groove of the other. The second pair of rolls consist of two similar rolls—that is, rolls each of which has in it a groove semi-circular in cross-section, the opposed grooves having the same radius as the

finished tube. Between the first and second pair of rolls the die, having a trumpet-shaped axial hole in it, is situated, the said die being fixed close to, but without touching, the

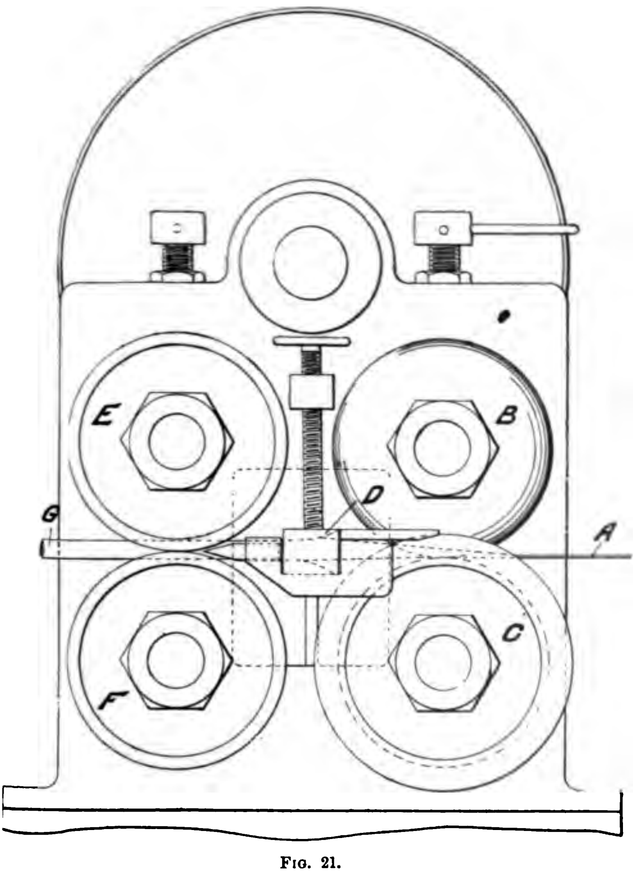


FIG. 21.

rst pair of rolls. The wide end or mouth of the bell-haped opening is turned towards the first pair of rolls.

The rolls are geared together with ordinary gearing and are driven by steam or other power.

The action of the machinery is as follows :—

The machine is situated near the furnace in which the flat strips of iron or steel to be made into tubes are heated. The end of a heated strip marked A, in fig. 21, is taken hold of by the workman by means of a pair of tongs, and introduced between the first pair of rolls B C. The strip A, seized by the rolls B C, passes rapidly between them and is bent into a semi-tubular form. Emerging from the first pair of rolls B C, the trough-like strip indicated by dotted lines in fig. 21 is forced by the rolls B C through the trumpet-shaped axial opening of the die D, the axis of the

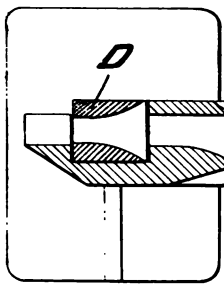


FIG. 22.

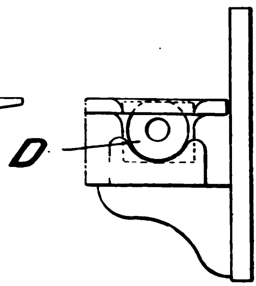


FIG. 23.

said opening being in a line with the axis of the "eye" of the rolls B C. The trough-shaped heated strip of iron or steel in passing through the die B is bent into a tubular form, and on leaving the said die passes between the second pair of rolls E F, the eye of which is in the same line as the axis of the trumpet-shaped opening in the die D and the eye of the first pair of rolls B C. By the action of the second pair of rolls the drawing of the tube through the die is completed, and the surface of the tube is improved. The finished tube passing from the rolls is marked G.

The heated strips of iron or steel may be made by this machinery, the inventor states, into welded butt-jointed

tubes, or into unwelded tubes, commonly called open-jointed tubes or close-jointed tubes.

When butt-welded tubes are to be made, the edges of the strip are presented face to face, and the width of the strip is such that when it passes through the die D the edges are pressed forcibly together and welded.

In making welded tubes the strips are raised to a welding heat, and passed through the machine quickly. When unwelded tubes are to be made, the strips are heated only to bright redness, and need not be passed so rapidly through the machine.

In 1894, F. R. Broughton, of Handsworth, Birmingham, in conjunction with J. Fieldhouse, filed a specification, No. 8563, of 1894, in which they describe a method of forming closed-jointed tubes entirely by rolling operations, dispensing with the use of an intermediate die. Their patent is in force. A list of other patents relating to this class of tubing will be found in the appendix.

The Manufacture of Tubes from Coiled Strips.

As we have already seen, the early process of gun-barrel making consisted in the welding of a tubular skelp, but it was well known many years ago that a stronger barrel could be produced, and many were made, by winding a ribbon or narrow strip of iron on a mandrel in a spiral direction and welding the edges together.

In 1857, Edgar Brooks, of Birmingham, filed a specification, No. 1603, for a "New and improved manufacture of gun barrels and other articles of like manufacture." The inventor says: "I take a rod of iron, and coil it in a helical direction upon a cylindrical rod or mandrel, the coil of the helix being brought as close as possible into contact. The said coil is then submitted to the compressing or percussive action of a pair of dies, each of which is nearly a hollow semi-cylinder. The coil is compressed or hammered between the said dies until it is welded into a compact hollow cylinder. In order to secure the lateral welding of the coils together, the interior of each die is provided with a series of projecting ribs, having such a figure that when the

two dies are brought together they form a hollow cylinder, on the interior of which is a helical coil of the same pitch

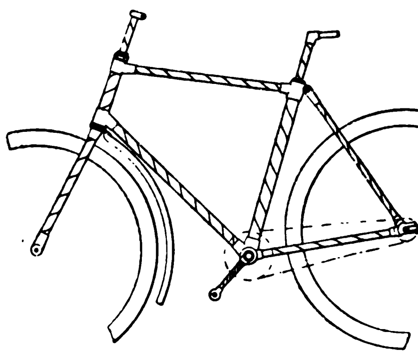
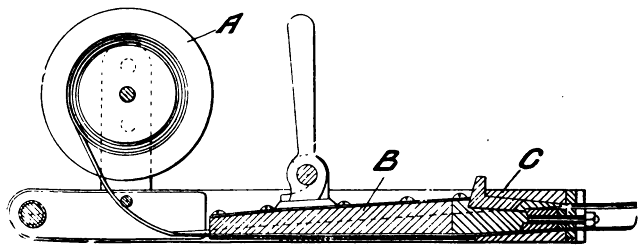


FIG. 24.

as the coil to be welded. The heated coil is so placed between the dies that the projecting ribs in the said dies press when the dies close upon the middle or edges of each

FIG. 25.



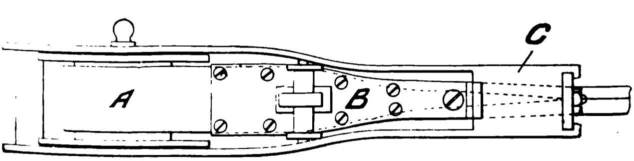


FIG. 26.

coil of the iron helix. By pressure upon the middle of the coils the said coils are made to spread laterally, and press against each other with great force. By pressure upon the edges of the coils nearly the same effect is produced."

The tubing forming the framing of the bicycle illustrated at fig. 24 is from the specification of William Hillman, of the Premier Cycle Works, Coventry, No. 82, of 1892. The invention, it is stated, consists in the employment in the construction of the framing and other parts of a cycle of tubing formed of sheet steel, preferably of the character known as crucible cast steel, it being essential that the steel employed should be of high quality. The tubing is formed by coiling a length of such sheet metal, of the desired width, around a mandrel in such a manner as to

FIG. 27.

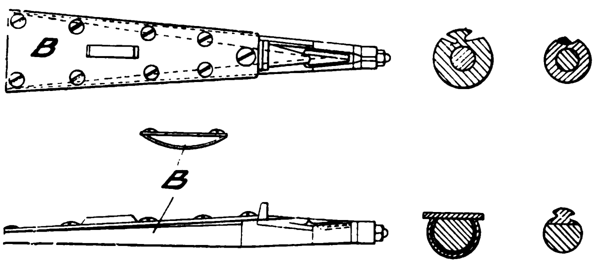


FIG. 28.

obtain at least two layers of metal all along the tube. The layers are jointed by soldering or brazing at the ends; or, if desired, at intervals, or all along the length of the tube. This patent is still in force.

LOCK-JOINTED AND BRAZED OR SOLDERED TUBES.

With lock-jointed tubing the edges of the strip are locked or caused to engage the one with the other, either on the interior or exterior of the tube. They are usually produced by rolling processes, but in the specification, No. 1415, of 1873, an American, S. R. Wilmot, describes the making of such tubes by a drawing process, as illustrated by figs. 25 to

29, inclusive. The strip of metal (such as brass, copper, steel) coiled or wound on the reel A, figs. 25 and 26, is dra

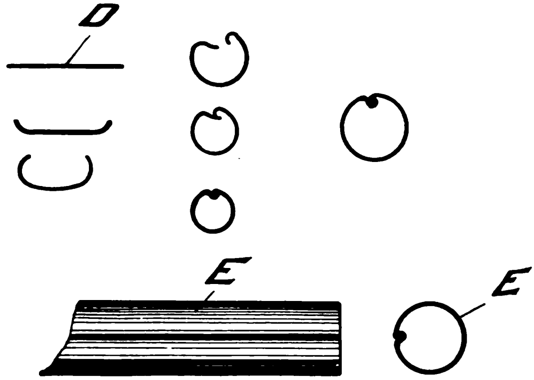


Fig. 29.

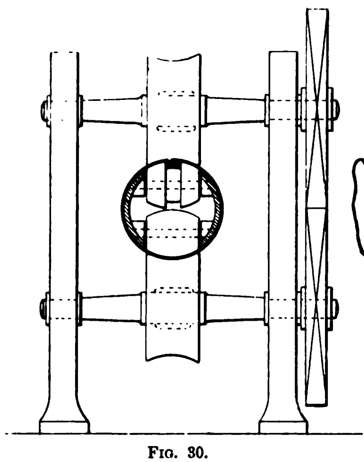


Fig. 30.

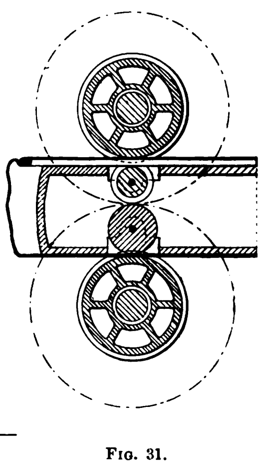


Fig. 31.

through the former B and die C, which are suitably sh to bend the flat strip D through the varying forms sh at fig. 29 to make the complete tube E.

The illustrations, figs. 30, 31, and 32 show the method of interlocking the edges, as set forth in the specification of J. Gaskell and G. Exton, of Chippenham, No. 5117, of 1883. This patent became void in 1888.

The illustrations at fig. 33 are from the specification, No. 19230, of 1891, of J. Earle and G. Bourne, of Birmingham. The patent granted on this application is now void through non-payment of renewal fee. The tubes shown are not, as

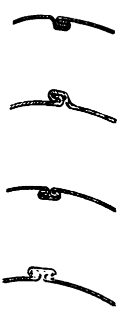


FIG. 32.

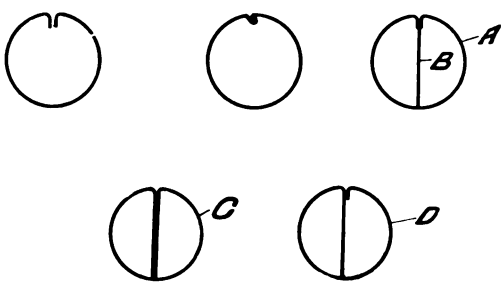


FIG. 33.

will be observed, lock-jointed, but the edges are turned inwards, and jointed by hard soldering. In the form shown at A, a strip of metal B is employed to give greater strength, such strip extending longitudinally throughout the centre of the tube. In the form at C the strip is of such width as to permit of both edges extending across the tube, as shown, whilst at D only one of the edges extends diametrically across the interior of the tube.

CHAPTER IV.

Seamless Steel Tubes.

In the initial stages of the application of a new mat
to the production of old or known articles, the metho
manufacture adopted is usually on similar lines to
method or processes by which the old material is wo
into the required form. From such initial stage we fi
constant development or advance, as a result of the ex
ments, the research and the ingenuity of the various m
directed to the subject. Thus the manufacture of seam
steel tubing, as first suggested or adopted, comprised no
process or method of treatment, but was merely an app
tion of the old or known appliances for dealing with the
material.

The ductility or flowing property possessed by steel blo
or billets, as produced by the modern methods of steel m
facture on a large scale which have given birth to what
been termed the "Age of Steel," suggested to tube ma
that such blooms or billets could be treated in the s
manner as copper, brass and other metals. Hence we
several patent specifications setting forth the productio
tubes from steel by processes similar to those employe
the manufacture of brass and like tubes.

In his specification, No. 472, of 1854, J. D. M. Stirling
Birmingham, states that "Heretofore in the manufactur
tubes and cylinders of steel it has been usual to em
sheets of steel bent into the size and form desired, and t
to join the edges by welding or brazing. Now, my inven
consists of casting steel into tubular or hollow cylind
rms, and then extending them in diameter or length
th, by hammering, by drawing, or rolling, or by combi
h processes. I cause cylindrical or tubular forms,
h and diameter according to the length and diam
e or cylinder intended, to be cast of cast steel in a
o what has heretofore been practised when mak
per or of brass, or solid ingots of cast steel,

it is found preferable to allow such steel castings to cool first; they are afterwards heated to the usual temperature at which cast steel is hammered, and I prefer tilting or hammering all such cylindrical or tubular forms previous to drawing

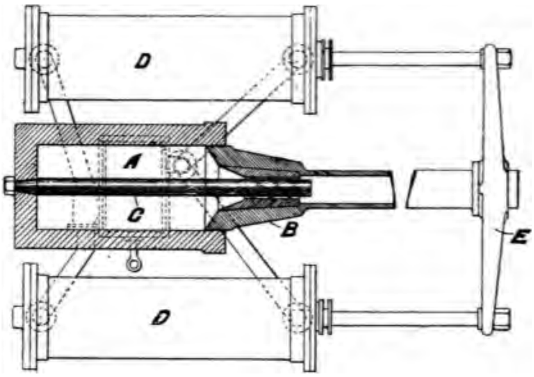


FIG. 34.

through plates or extending by means of rolling." The inventor proceeds to state that the tubes are heated and annealed as may be necessary, and are drawn to the required size with mandrels and dies such as are used for drawing brass tubes.

SEAMLESS TUBES DIRECT FROM MOLTEN OR PLASTIC METAL.

Before referring to specifications setting forth processes by which seamless steel tubes for cycle construction and other purposes are now produced, we may here note the specification No. 846, of 1882, of R. Elliott, of Newcastle-on-Tyne, setting forth a method of producing tubes with the grain or fibre of the metal in a helical direction. The tubes are made direct from the liquid or plastic metal by a process similar to that employed for squirting lead pipes. The adjoining figs. 34 and 35 are from those accompanying the specification. Referring to fig. 34, the metal, in a molten or plastic condition, is placed in the vessel A, having at one

end a head piece B, carrying a hollow die of steel o hard metal, in which is formed grooves in a helical oı like direction. Projecting into this die is a bar or secured to the lower end of the vessel A. On pressur

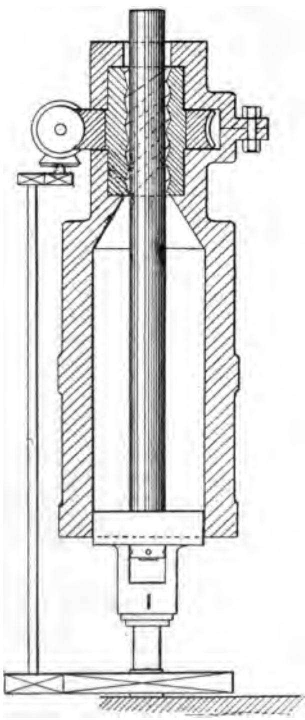


FIG. 35.

applied to the metal in the vessel A, by means (working in the hydraulic cylinders D, such rams connected by rods to the crosshead E as illustrated, t metal is forced from the vessel A through the annula between the rod C and the die, and is caused by the

in the die to take a helical or screw-like course there through; it will thus issue from the hollow head piece B as a tube with a helical or twisted fibre. The die may be caused to rotate in the manner illustrated at fig. 35.

A process of making tubes of iron, or steel, or other metal or alloys, by pouring or passing a tubular stream of molten metal in contact with continuously moving chilling surfaces, is described in the specification No. 19153, of 1890, of Edwin Norton and Edmund Adcock, of Illinois and Chicago respectively. The patent became void in 1895.

The Application of Punching or Extending Processes for Producing Steel Tubes from Discs or Blanks.

In his specification No. 5265, of 1885, W. H. Brown, of New York, states: "In the manufacture of drawn-steel cylinders and tubes from discs of steel, as heretofore practised, the entire process has been performed with the metal in a cold state. This process is expensive, owing to the enormous power required for working the metal in the earlier of the numerous successive drawing operations required when the thickness of the metal is great, and the calibre of the cylindrical cup-formed body being operated upon is large." The invention of Brown is said to consist in performing the various operations partly while the steel is hot and partly while cold—that is to say, performing the earlier stages of the manufacture by which the disc is brought to the cylindrical form while the steel is hot, and performing the latter stages by which the steel is compressed, condensed, solidated and tempered while it is in the cold state. Referring to fig. 36, A is a sectional view of the disc from which a cylinder is formed, whilst B, C, D and E are similar views illustrating the different forms assumed by the disc during its working in a hot state. F, G, and H are views illustrating the means employed to effect the successive changes of form. The closed end left in the cylinder is cut off at the termination of the hot folding operation, and the tube is finished to the required size by a cold drawing with die and triblet, or mandrel. This patent became void in 1891.

In the specification No. 11095, of 1891, of J. S. Tayl
S. W. Challen, of Birmingham, there is set forth a se
operations by which a tube is formed from a disc or
of steel by subjecting the metal when in a cold stat

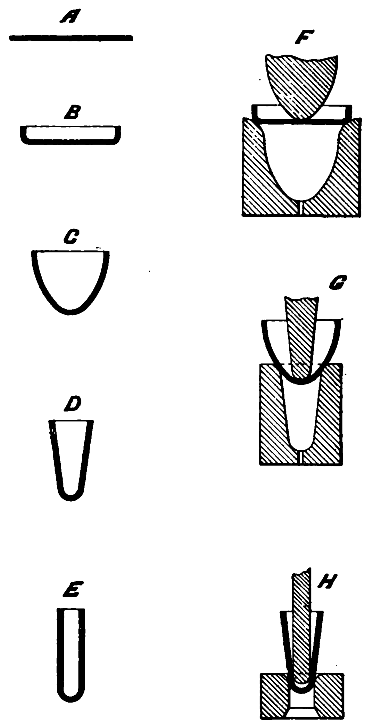


FIG. 36.

series of cupping operations, whereby the thickness
original disc or sheet is maintained approximately the
throughout such operations, and afterwards subjectin
long cup thus produced to cold-drawing operations to fi
lengthen, reduce in thickness, and polish the tube.

blank or disc is cut from a cold steel sheet, and extended in the manner illustrated by the sections A, B, C, D, E, F, G, H, and J, fig. 37, and is then transferred to the draw benches,

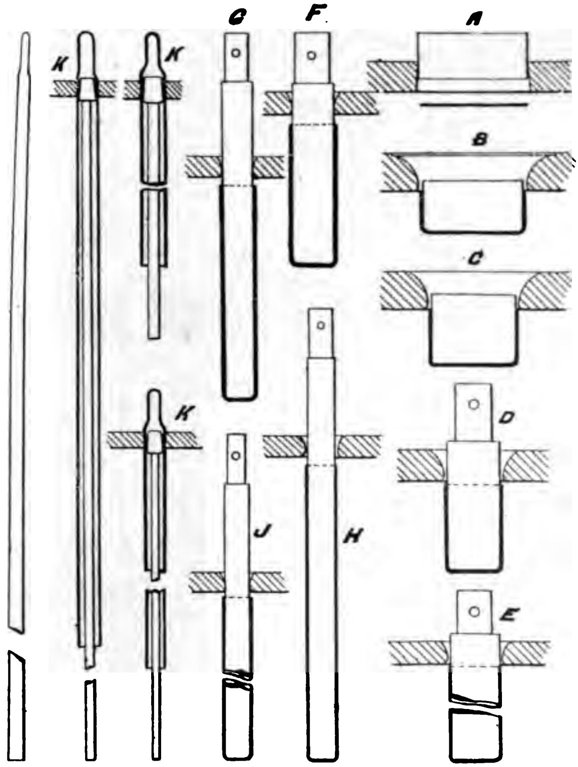


FIG. 37.

and drawn out and finished to the desired diameter and length by means of die plates such as K, in conjunction with mandrels, having conical ends to permit of varying thicknesses of tube being produced, adjustment of the mandrel being effected by a screw and nut at its outer end.

To facilitate the operation of drawing the tube
solid end is closed in or necked as at L, fig. 3
extending operation, to permit of a firm grip or

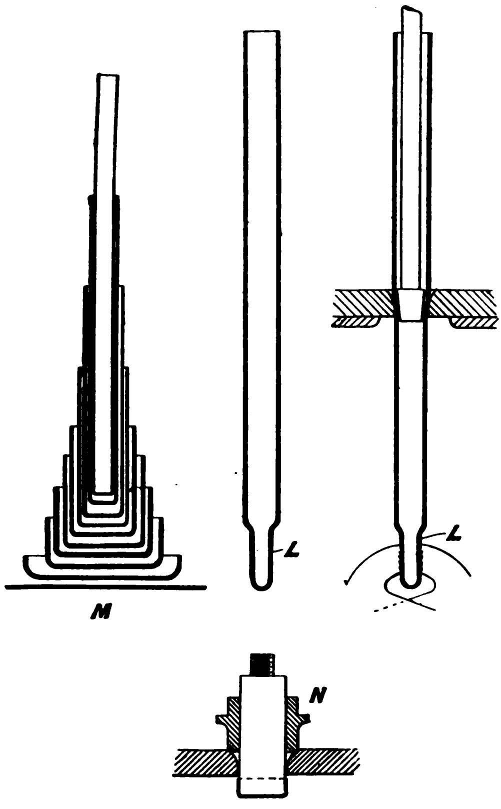


Fig. 38.

obtained by the tongs or like appliances employed
drawing the tube through the die. The series of operatic
through which the sheet passes is shown at M, fig. 38. N

a detail of the first stage of the cupping process. This patent is in force.

Fig. 39 is from the specification No. 20364, of 1891, of C. T. Cayley and R. S. Courtman, of London, describing an invention relating to the manufacture of cylinders or bottles for containing oxygen and other gas under pressure. The

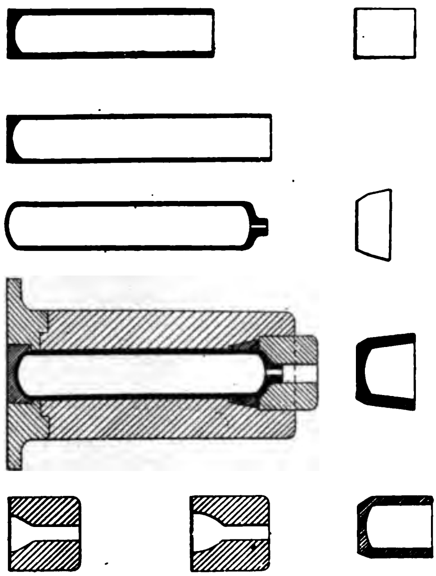


FIG. 39.

ttles are produced from a solid block of steel, which is rked into a cup-shaped blank by punching while in a uld, then made into a tubular form by hot drawing, and shed by cold drawing and closing of the open end. This ent became void in the year 1898.

CHAPTER V.

The Mannesmann Process.

The first patent application made on behalf of the German manufacturers, Reinhard Mannesmann and Max Mannesmann, is dated January 27th, 1885, and the complete specification filed therewith is No. 1167 of that year. The title of the specification is given as "Improvements in rolling metal, and in apparatus therefor," and the invention is said to "embrace and relate to a process of and apparatus for rolling solid or hollow metal blocks or pieces, and thereby imparting to them various dimensions, shapes, sections, or longitudinal forms." The specification proceeds:—"The process consists firstly in imparting to the piece to be rolled a rope-like twist as regards the outer fibre. For this purpose the block or piece is made to rotate between two plain discs, or between two or more conically-shaped or otherwise formed rollers, and thereby to advance slowly. In consequence of the different speed of rotation of the two ends of the blank, a twist similar to that of a wire rope is imparted to the fibre of the rolled product. The blank successively passes between narrow passages of the discs or rollers, and is thus brought or reduced to any desirable small dimensions as regards section."

In the drawings accompanying the specification is illustrated the apparatus for rolling various dimensions of round iron with two plain discs. These discs are arranged with horizontal axes somewhat inclined to each other, and the one axis is a little higher than the other. The inclination of the two axes in relation to each other may be varied to obtain various alterations of form, and the difference in the height of the axes may also be varied. A conical space is thus formed between the working faces of the discs, and the material is introduced on the wide side or end of the space. The discs revolve in opposite directions and besides rotating the blank they impart to it a forward motion, varying with the difference in their levels.

The drawings of the same specification also illustrate a method of rolling with an oblique or diagonal mill, having rolls mounted in bearings provided with means for the necessary adjustment to effect the oblique rolling of blanks of various dimensions. Tubes are formed with such an oblique or diagonal mill by fixing a mandrel in front of the centre of the blank.

In the following year (1886) the same applicants filed a specification, No. 9939, 1886, setting forth an invention which they describe as "An improvement upon and further development of the method of rolling solid or hollow blocks of metal," for which letters patent, No. 1167, of 1885, were granted. The inventors state that their process "consists mainly in working upon the outside of a solid blank by external rolls or rollers in such a manner that the blank assumes a tubular shape, either no core or mandrel being employed in such cases, or else a core or mandrel being employed for the purpose of smoothing the inside of the pipe or tube thus formed, reducing the thickness of its sides or shell, and enlarging its internal diameter."

The illustrations at the adjoining fig. 40 are selected from the drawings accompanying the 1886 specification. Referring to the elevation and plan at A, the axes of the discs or rollers are placed at an angle to each other, as illustrated, and the block of metal *a* to be operated upon has a rotary and at the same time a horizontal motion imparted to it.

In the arrangement shown at B the rollers are arranged over and under each other, the axes being inclined, whilst C represents another side-by-side arrangement. At A the working takes place between the lateral, but at B and C between the circumferential surfaces of the rollers. Towards the egress side the distance of the rollers from one another becomes less, so that the piece of metal has a spiral motion on its emergence from the rolls. Lateral guides, as *b*, are provided for the purpose of regulating the motion of the blank *a*, and such guides may be fitted with rollers, as at D, to obviate excessive heating by friction during working.

"When the blank has been sufficiently heated to make it soft enough, or if possessed of a sufficient degree of plasticity at ordinary temperature, and if during the passage through

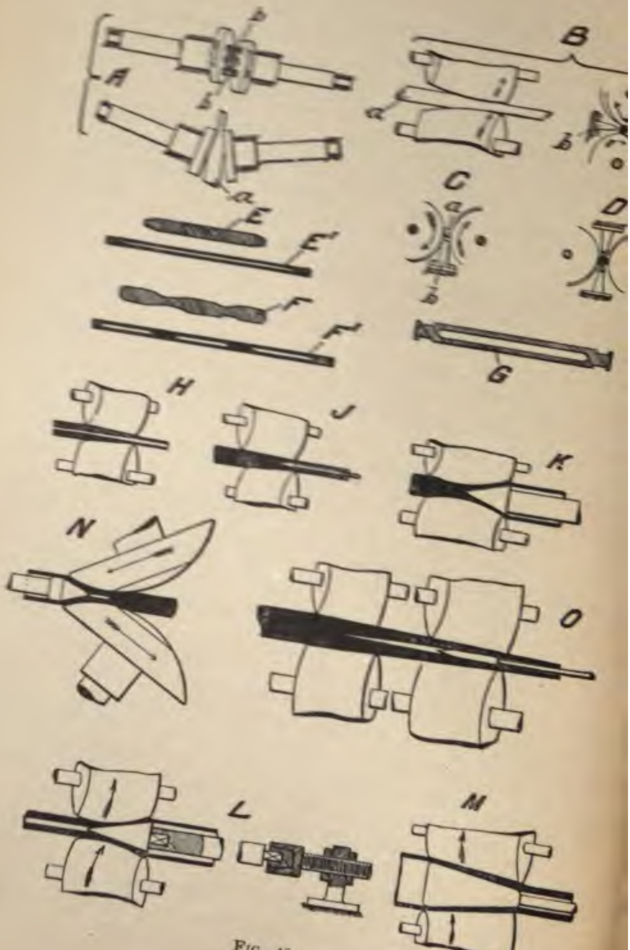


FIG. 40.

the rollers a [illegible]
transfer of metal [illegible]
of the blank is [illegible]
displacement [illegible]
without the use [illegible]
case if a cast-[illegible]
the spiral [illegible]
from each [illegible]
blank forms [illegible]
of 1·2 in. [illegible]
sions of the [illegible]
stances, to [illegible] —

"1. The [illegible]
takes place [illegible]
largest when [illegible]
circular [illegible]
the nature [illegible]
area of the [illegible]
position, the [illegible]
ascertained [illegible]
varies the [illegible]
and the [illegible]

"2. The [illegible]
more central [illegible]
will be, and [illegible]
the blank [illegible]
the nature [illegible]

"3. The [illegible]
are being [illegible]
mences [illegible]
size of the [illegible]
the external [illegible]
limit, as the [illegible]

"4. The [illegible]
together.

"5. The [illegible]

"6. The [illegible]
or angular projections, [illegible]
roller or at an angle [illegible]
tion of the hollow, because [illegible]

superficial area of the blank. For the purpose of varying the size of the hollow, the position of the rollers may be adjusted while the work is going on, or during the intervals, by means of suitable levers or hydraulic arrangements."

"If a solid piece of metal, as E, has its ends bevelled or tapered down, or if its thickness is reduced at one or more places, as the sample F, then if such piece of metal is passed through the rolls it becomes tubular in the parts that were originally thick, and remains solid at those parts that were reduced in size, as illustrated at E^1 and F^1. Billets formed as E^1 may be used for railway axles such as G. Where the billet or blank is hollow at the outset, the hole may be enlarged by the proper adjustment of the position of the rollers while the process is going on, and this enlargement may take place although the diameter of the blank itself is being reduced, as illustrated at H. By means of a core or mandrel a greater amount of smoothness may be given to hole. The mandrel shown at J is prevented from sliding in the direction of its axis, and the blank rotates over it in the form of a pipe. The diameter of the finished pipe or tube may be equal to, larger, or smaller, than that of the original blank, but in practice the adjustment is to be made in such a way as to add to the tendency of the hole to enlarge itself. To this end the core or mandrel is made thicker at one end, as shown at K. With a screw and nut arrangement, as at L, the thickness of the tube may be varied by adjusting the position of the conical mandrel. In the arrangement shown at M the mandrel shaft is in tension instead of compression, as in the previous cases. In the arrangement shown at N the duty of the core or mandrel is simply to enlarge the hole; it takes no part in the initial formation of the hole. A combination of two sets of rolls is illustrated at O."

In connection with the foregoing the reader should refer to Chapter VIII. of this edition.

The illustrations at fig. 41 are from the drawings accompanying the specification No. 666, of 1887, filed on behalf of the Messrs. Mannesmann. The shape and arrangement of the rolls is thus described in the specification: "Two or more conical rollers, the working surfaces of which are inclined in a manner to give a conical shape to the blank

between them, are arranged obliquely to each other, to revolve in suitable bearings, so constructed that all or any of the rollers may be adjusted laterally, vertically, and in respect of the angle of inclination to its fellow or fellows. All the rollers are laid in the same direction—that is to say, the ends of larger diameter are all situated at the same end

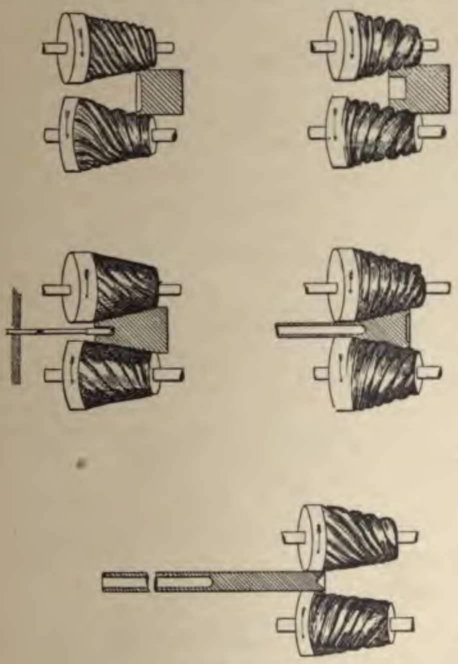


FIG. 41.

of the apparatus. The peripheries of the rollers have formed on them a number of helical corrugations, so that a blank or block of metal fed in between the rollers at the one end of the apparatus issues from the other end in the form of a pipe or tube, a cylindrical passage being formed through a part of the length of the same. The said corrugations gradually

disappear towards the end of the emergence, in ord produce an externally smooth tube, and this is effectually attained by making the end parts of the r cylindrical, as shown in the accompanying drawings. rollers are caused to revolve, by any suitable power

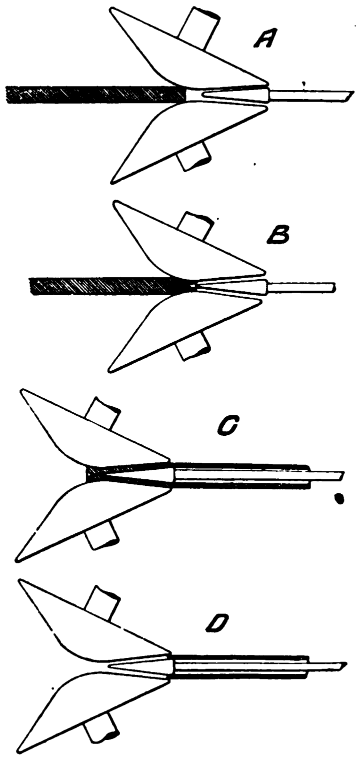


FIG. 42.

gearing, in the same direction, so that the working sur move in opposite directions, rolling the blank bet them."

The illustrations at fig. 42 are from the drawings ac panying the specification No. 6453, of 1887, filed on beh

Messrs. Mannesmann, representing a further development of their method of transforming solid ingots of metal into tubes. A is a plan of a pair of hemispheroidal rolls mounted upon the opposite ends of two converging shafts, having suitable portions of their working faces convergent and the remaining portions divergent, showing a conical mandrel interposed between the divergent portions of the working faces, and also showing in longitudinal section a solid metallic blank which has been seized by the convergent portions of the working faces and has commenced its passage between the rolls. B is a similar view representing the blank as having so far progressed between the rolls that there has been formed at its forward end a tubular recess, into which the pointed end of the mandrel projects. C represents the blank so far progressed between the rolls that the rear end has been carried nearly to the point of the mandrel, whilst D shows the conclusion of the tube-forming and enlarging operation.

From a paper on the Mannesmann process, read before the British Association Bath meeting, in 1888, the following observations are selected, as they may perhaps assist the reader in appreciating the essential features in the arrangement of the apparatus :—

"In the ordinary rolling of iron bars, sheets, &c., we have 'longitudinal rolling.' In rolling for the purpose of straightening or polishing bars, two or three rolls are employed which revolve in the same direction, and the bar is inserted at the ends of the rolls, or in the direction of their longitudinal axis, instead of at right angles thereto. With such rolling the bar is *not* drawn forward, but simply rotates, and if sufficient pressure is applied the bar is elongated, but no decided fibre is produced. This may be termed 'circular rolling'—that is, the bar is rotated. In the Mannesmann process two or three rolls may be employed turning in the same direction, thus imparting a rotative movement in the opposite direction to the bar to be operated upon. The two or more rolls are, however, arranged at an angle with each other in such a manner as to impart also a forward motion to the blank."

The following patent applications have been filed by or

on behalf of Mannesmann, subsequently to those previously noted: No. 9754, of 1888; No. 3371, of 1891; No. 4595, of 1892; and No. 7153, of 1892. The three last-named patents are in force. See also list given in appendix.

The Stiefel Process.

The specification No. 23702, of 1895, of Ralph Charles Stiefel, of Pennsylvania, U.S.A., has attracted much attention in this country. The illustrations at fig. 43 are from the drawings accompanying this specification, which is entitled, "Improvements in mechanism for piercing solid metallic ingots or blanks," and the inventor states that his object is to pierce metallic blanks or billets in a heated state without subjecting them to torsional strain or materially disturbing the longitudinal arrangement of the fibres of the metal. The mechanism for accomplishing this object consists of a pair of specially constructed and arranged parallel discs and a piercing mandrel, by means of which the heated blanks or billets may be drawn and pierced at one operation. In this operation a blank is passed between the adjacent faces of the two parallel discs, which impart to it a rotary motion, and at the same time a longitudinal motion which forces it against a conical piercing mandrel lying in the path of the axis of the blank; the arrangement of the working surfaces of the discs is such that a practically uniform speed of rotation is imparted to each and every portion of the blank lying between and being acted upon by them, thus producing a drawing action upon the blank that does not materially alter the longitudinal arrangement or relation of the fibres in the blank, or in the final product thereof, during any changes wrought in its diameter. The grip of the disc on the blank gives sufficient power in its forward and rotary movements to force it on to and over the mandrel, which thus pierces its centre. The mandrel may be fixed, or it may be rotated at a speed different from the speed of the blank, in order to impart to it a more or less energetic boring effect in penetrating into the blank.

A, fig. 43, is a plan view partially in section of the pair of discs, with a piercing mandrel the point of which is between

the working surfaces and a blank, or billet, embraced by the discs and undergoing the process of being pierced by the mandrel. B is a side view of the same, some of the parts being broken away to more clearly illustrate the construction

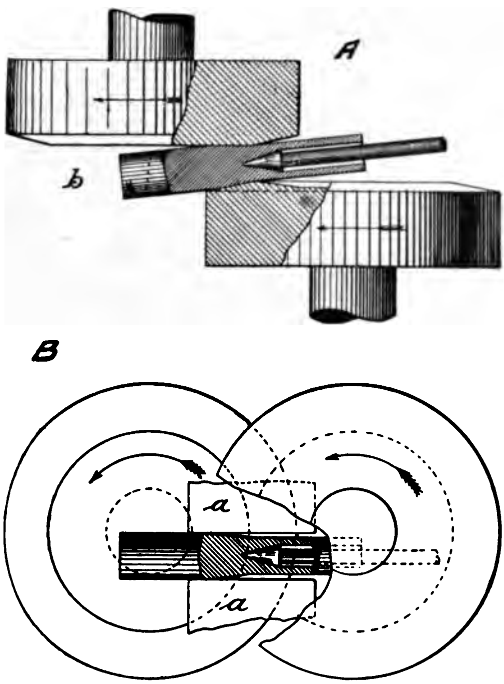


FIG. 43.

of those behind them. The blank enters the "pass" between the rolls or discs from the side *b*, and is gripped, revolved and forced by the rolls over the mandrel as illustrated. The guide blocks *a* are employed to hold the blanks in proper position.

CHAPTER VI.

Various Processes and Machinery Relating to the Manufacture of Seamless Steel Tubes.

The Credenda Tube Co.—The improvements described in the specification, No. 12823, of 1885, of W. C. Stiff and H. B. S. Bennett, of the Credenda Tube Co., of Birmingham, have reference to the formation of the axial hole in the ingot or bloom from which the steel tube is made. The inventors state that "in the ordinary methods of manufacturing seamless steel tubes, a solid cylindrical ingot or bloom or bar is formed by rolling or hammering or by casting, and an axial hole is made in the said ingot or bloom by drilling or punching, the partly-made tube being completed by rolling and drawing in the ordinary way; or the said hole is formed in the casting process. According to our invention, we first drill or punch a small axial hole in the said ingot or bar, and afterwards enlarge the said hole to the required diameter by a drawing process conducted in the following manner: We fix the axially-drilled cylindrical ingot or bar on a bed or holder, and while the said ingot or bar is so fixed we enlarge the small axial hole in it by means of a bulb mandrel worked by a powerful draw bench or machine, the rod or stem of the bulb mandrel being passed through the small axial hole in the ingot. By the action of the bulb of the mandrel upon the axial hole through which it is drawn the said hole is expanded to the required diameter, the metal thus displaced expanding radially, and increasing the external diameter of the ingot or bar. The steel ingot or bar is at the same time consolidated. The ingot or partly-formed tube, after the hole in it has been increased in diameter to the required extent, r [illegible] by a rolling or drawing operation, be diminished in [illegible], and the ingot again subjected to the action of the [illegible]drel, so as to again increase the diameter of [illegible] [illegible]stead of drawing the bulb mandrel through the [illegible] bulb mandrel may be stationary, and the

got or bar drawn over the same, or the mandrel may be ished through the ingot or bar. In this way the ingot or rtly-made tube may be consolidated to any desired extent, d an axial hole of the required diameter formed in it. hen we make the small initial hole by drilling, we effect drilling while the ingot or bar is cold; but when such

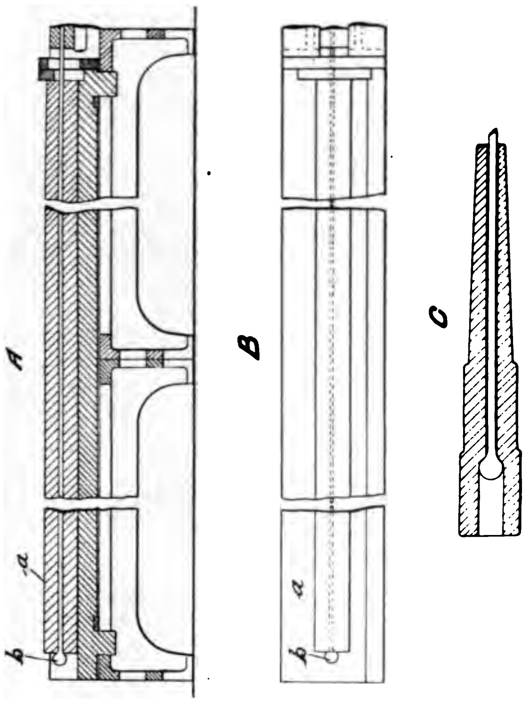


FIG. 44.

is formed by punching, we effect such punching on a ɔd ingot or bar. All the subsequent processes we rm while the ingot or bar is hot. The improvements ibed may be applied to the manufacture of tubes and ınce, made either of steel or iron."

The illustrations at fig. 44 are from the drawings accompanying the specification, A being a longitudinal section, and B a plan of a draw-bench arranged for the enlargement of the small axial hole in the ingot *a* by the bulb-headed mandrel *b*. C is a section representing the enlargement of the hole in a taper tube, suitable for the manufacture of ordnance.

Drawing Tubes with an Internal Taper.—In his specification, No. 1449, of 1876, describing a process of tapering steel tubes, Thomas Rickett, of Birmingham, states: "It is commonly known that locomotive boiler tubes are invariably made taper inside and parallel outside—that is to say, nearly double the thickness at the firebox end to that at the smoke-box end. This is done in order to have the greater thickness where the most wear exists, and the lesser thickness where not required for wear and tear, to economise cost and weight, and also because a thinner tube conducts heat more rapidly than a thicker one. Brass and copper tubes are made taper inside by drawing them upon a taper bar or mandrel the entire length of the tube and afterwards stripping the tube off the mandrel, a process which is not practicable for steel tubes; and at present, to the best of my knowledge, there is no plan existing by which steel tubes may be drawn with an internal taper, as desired, for boiler tubes."

The inventor then proceeds to state that, "in the process of drawing steel tubes the tubes are usually drawn over a fixed bulb-headed mandrel, adjusted so that the centre or largest part of the bulb end is in the centre or smallest part of the die, and my improved plan of tapering consists in having a short taper mandrel or plug arranged so that during the process of drawing the tubes through a fixed die the taper mandrel or plug is moved forwards or backwards as required, by any suitable mechanical means, and it is evident that if a tube be drawn over a taper plug when the small end is in the centre of the die, the tube will be of a thickness equal to the annular space between the small end of the plug and the centre of the die, and if another tube be drawn over this same plug when the large end is in the centre of the die, the tube when drawn will be thinner than

e previous one in proportion to the taper on the plug. f, now, the same plug is made to change its position with egard to the die by mechanical means during the process f drawing, the small end being in the centre of the die when the tube is beginning to be drawn, and the plug gradually moving forwards until the large end is in the

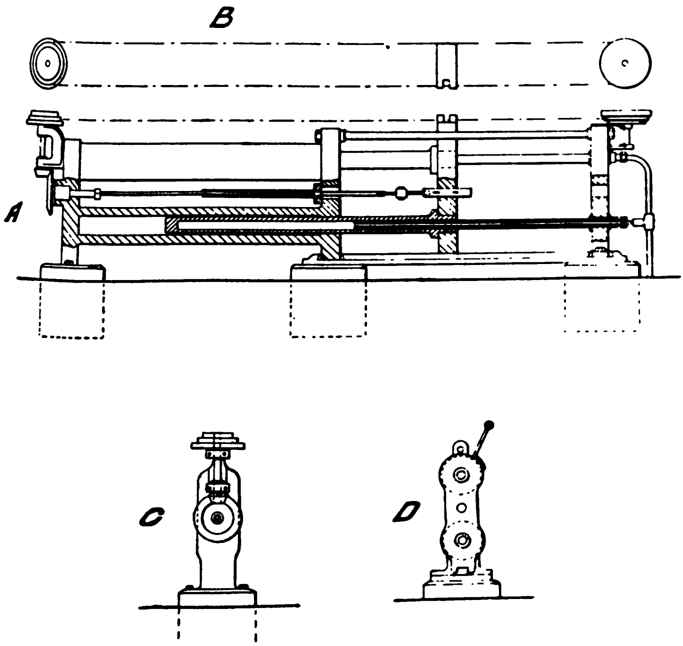


FIG. 45.

centre of the die at the finish of the drawing, a tube will be produced having an internal taper corresponding to the taper on the plug, and proportionate in length to the relative speed by which it is made to traverse; that is, if the length of the tube to be drawn is 12 ft. when finished, and the length of the taper required on the plug be 1½ in.

then the speed of the bench compared with that of the plug will be as 96 to 1, and for an 8 ft. tube as 64 to 1."

The illustrations at figs. 45 and 46 are from the drawings of Rickett's specification, A being a side elevation, partly in section, showing the tapering gear fitted to a hydraulic draw bench, and B a plan of such gearing. C is an end view showing the tapering gear, and D a transverse section of the draw bench. E, F, G, H, J, and K are sections to a larger scale, E representing the parallel tube passed over the taper plug and ready for being tapered by drawing it off again.

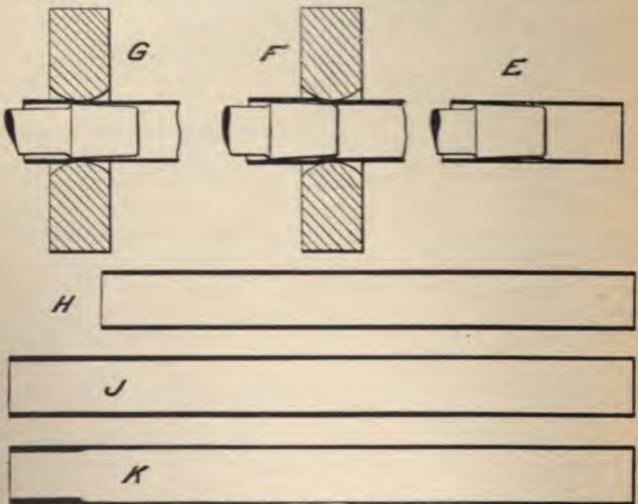


FIG. 46.

F shows the commencement of the tapering at the small end of the plug. G shows the completion of the tapering at the large end of the plug. H shows the section of a parallel tube, and J a section of the same tube after having passed ·rough the tapering process. K shows a similar tube with kened end, giving greater strength for fixing into boiler. ıtent lapsed, of course, some years since.

Tubes.—The illustrations at fig. 47 are from the ·ı No. 13357, of 1888, of William Pilkington, of

Birmingham, for "Improvements in the tapering of or reducing of tubes of iron, steel, or other metals, and in the ornamentation thereof." The inventor states that he constructs "one, two, or more dies or moulds, having in each a tapered aperture. If more than one die is used, each is locked or stayed to the other, thus forming an uninterrupted tapered passage; the number of dies varies according to

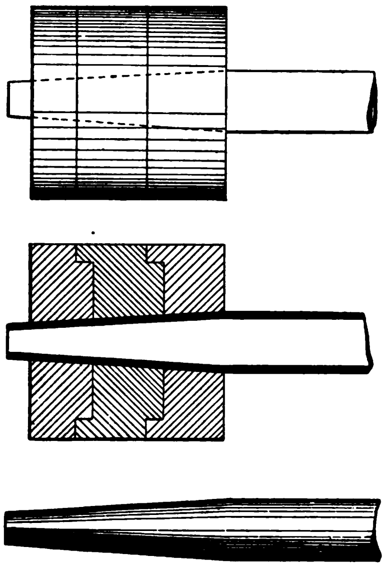


FIG. 47.

the length of the tapering of the tube. I take a tube of the required length and place it in or at the mouth of the aperture in the uppermost die, and by means of hydraulic or other pressure I force the one end of the said tube down the dies, and so taper or reduce the tube." This patent became void in 1892.

The illustrations at fig. 48 are from the specification No. 17090, of 1892, in the names of W. Pilkington, C. T. Bishop,

and others, for "Improvements in apparatus to be employed in the manufacture of metallic tapered tubes." The patentees state that their invention relates to "the converting of a parallel tube into a tapered tube by the employment of semi-elliptical grooved rolls, through which the parallel

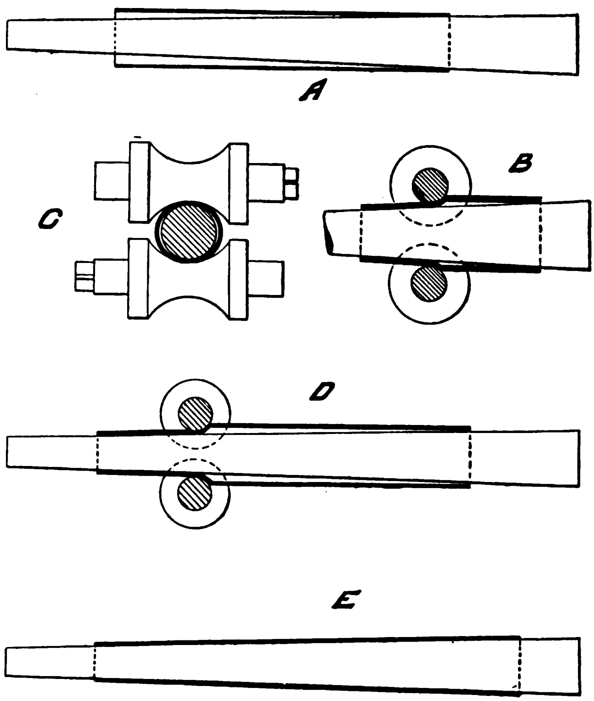


Fig. 48.

tube is passed when placed upon a conoidal mandrel under the yielding pressure or resistance of springs, steam, hydraulic, pneumatic, or other elastic or yielding power." A is a sectional view of a parallel tube upon a conoidal mandrel, preparatory to rolling and converting to a tapered tube. B is a section showing the process of the first pass

through the rolls. C is a view of the rolls, with formation of the tube upon the conoidal mandrel by the first pass. D is a section showing the second pass through the rolls, and E of the finished tapered tube on its mandrel. After

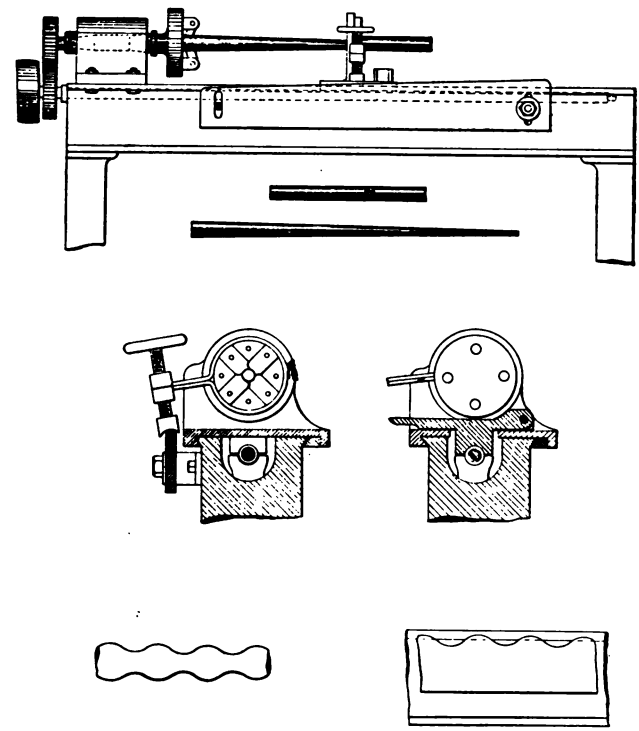


FIG. 49.

the first pass through the rolls, the tube and mandrel are turned through a quarter of a revolution, thus bringing the portions of the tube between the rolls which were not affected during the first rolling. The required pressure upon the upper roll is imposed, in the additional drawings

accompanying the specification, by means of a spiral spring which allows the roll to automatically adjust itself to the varying diameter of the mandrel. This patent became void in 1898.

The illustrations, fig. 49, are from the specification No. 15308, of 1885, of Henry Waters, of Birmingham, for "Improvements in the manufacture or production of tubes, rods, and other articles having a taper or undulating figure." The invention is stated to "consist preferably in the construction and arrangement of expanding and contracting dies, which are opened and closed in order to create a greater or less aperture or eye on the drawing of the die dish or carrier over a tube or rod to be tapered or shaped. The contraction and expansion of the segments of the dies which enclose or form the eye or aperture, is effected by an inclined plane or pattern, corresponding to the taper or figure of the object to be drawn, tapered, or shaped. This inclined plane or pattern acts in conjunction with the segments of the dies in such a manner that a tube, rod, or other object is drawn with a progressive taper, or with an undulatory or other figure, by the traversing and closing of the dies upon the object being fashioned, and during this operation the object itself is rotating. This rotation is simply to counteract any defects which may incidentally occur in the figure or formation of the acting parts of the die." This patent became void in 1890.

A process of making seamless steel tubes from an ingot having a core of yielding refractory material is set forth in the specification No. 1467, of 1888, of C. A. Marshall, of Pennsylvania, U.S.A. The illustrations at fig. 50 set forth the process. The ingot is cast of a form such as shown at A, having a core *a* of yielding refractory material, such as powdered graphite having dry fire clay mixed therewith, contained in a casing *b*. B represents the ingot reduced to a flattened blank by rolls or by external pressure. C represents the blank partially opened. D is a cross-section of the partially completed tube as it appears when ready to be drawn over the shaping ball or mandrel. E represents a cross-section through the partially completed tube and the point of a mandrel. F is a cross-section of

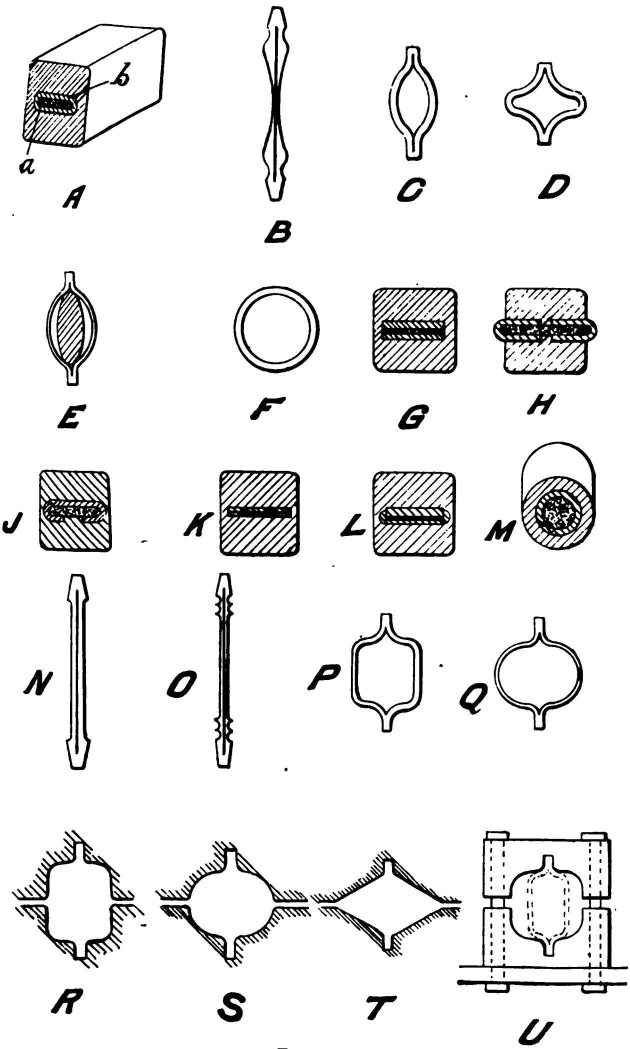


Fig. 50.

the finished cylindrical tube. G, H, J, K, L, M represent modified forms of ingot cores, and N and O modified forms of blanks. P and Q represent modified forms into which the blank may be partially opened. R, S, and T illustrate different forms of rolls for partially opening the blank, and U a set of guides. This patent was allowed to lapse before the expiration of full term.

The "improvements in the manufacture of solid drawn or seamless tubes and in machinery employed in the manu-

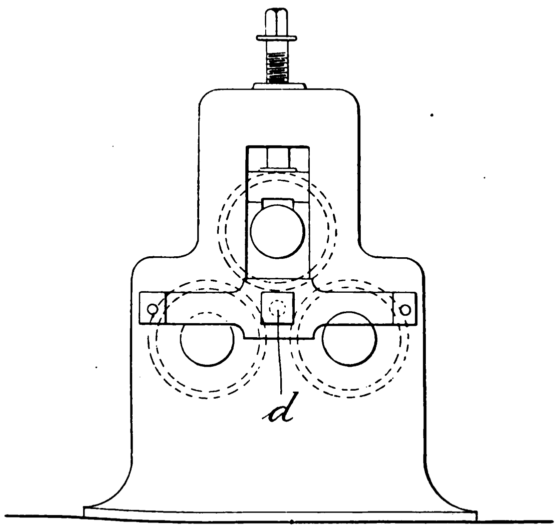


FIG. 51.

facture thereof," as described in the specification of W. Pilkington and others, No. 14278, of 1888, comprise the use three rolls with helical grooves extending along their aces. Fig. 51 is an end elevation, and fig. 52 a front ion of the rolls. The rolls are preferably of an equal and their axes are parallel or nearly parallel to The helical grooves extend from end to end. end *a* the grooves are deep, but as they

ceed along the rolls they become shallower, until, on ching the leaving end b, the depth is comparatively nil. e grooves in each of the rolls are of the same pitch, so at when the three rolls are rotated simultaneously at the ame speed and in the proper direction on their axes they orm in the triangular space where they meet, a kind of nut or internal threaded screw, so that any object fitting into the grooves of the rolls would be carried along from the

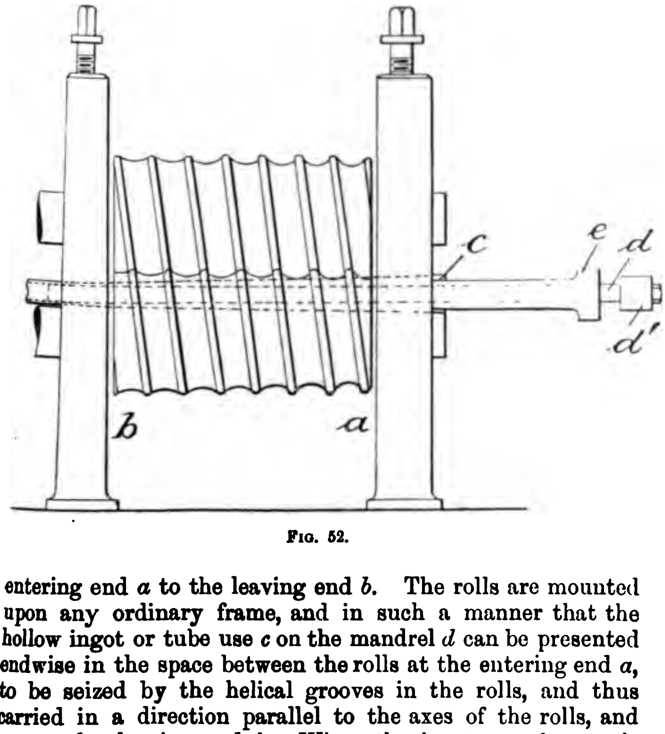


FIG. 52.

entering end a to the leaving end b. The rolls are mounted upon any ordinary frame, and in such a manner that the hollow ingot or tube use c on the mandrel d can be presented endwise in the space between the rolls at the entering end a, to be seized by the helical grooves in the rolls, and thus carried in a direction parallel to the axes of the rolls, and out at the leaving end b. When the ingot or tube use is first seized by the rolls it has deep impressions formed in it by the grooves, but as it passes along the rolls the grooves

become shallower, until finally on leaving the rolls the tube use is in the form of a hollow cylinder of smaller outside diameter than when it entered the rolls, but longer, and with its metal more dense.

To free the mandrel from the tube use after it has passed through the rolls, it is sometimes put through a pair of ordinary grooved rolls in a direction at right angles to the axes of such rolls, with the result that the tube is bulged to

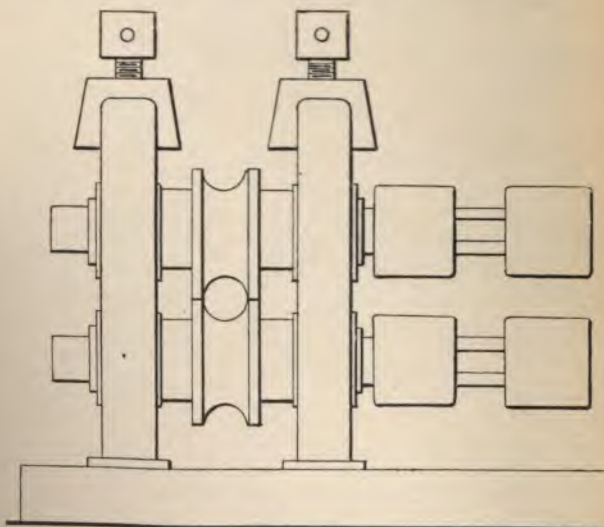


FIG. 53.

a sufficient extent to release the mandrel. The method of releasing the mandrel illustrated in the drawings consists the provision of a square head such as d' on the head of nandrel, which, when the tube use is nearly through the 'v-grooved rolls, is brought up and into a holder e, ins and prevents rotation of the mandrel d, but c by the action of the rolls is still carried us withdrawn from the mandrel and freed

at the leaving end *b*. The tube is finished by drawing on a mandrel through dies in an ordinary drawbench. This patent became void in 1893.

The specification No. 16934, 1889, of William Pilkington and others, of the Birmingham Climax Steel Tube Co., describes a process for the conversion of a cylindrical steel

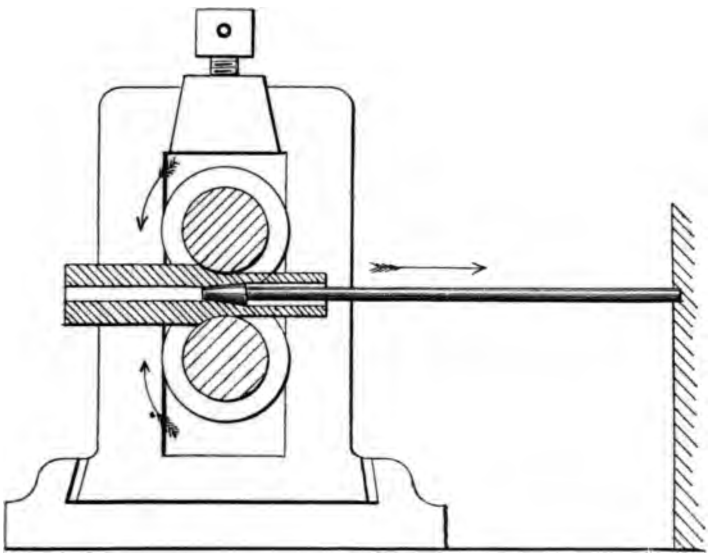


FIG. 54.

ingot into a comparatively short thick tube which is subsequently dealt with by other means. The process is illustrated at figs. 53 and 54. A comparatively small hole is first bored through the ingot in the direction of its length in the ordinary manner. The ingot is then heated, and there is forced into it at one end a mandrel having a loose conoidal end, and the hot ingot is then rolled over the mandrel in a tube-rolling mill such as illustrated. The mandrel is prevented from moving with the ingot which is

forced over it by the action of the rolls, and thereby lengthened, whilst the hole is enlarged. This patent became void in 1893.

The specification No. 9657, of 1893, by the same patentees, relates to the construction and arrangement of machines and

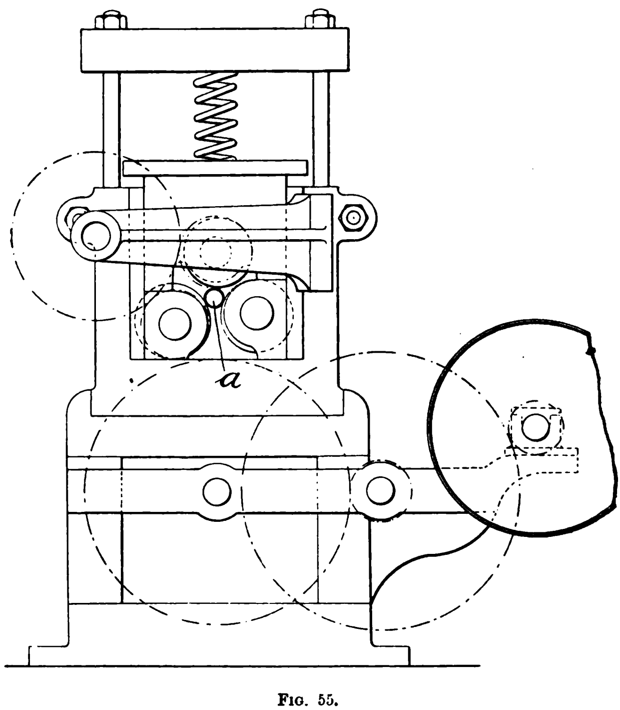


FIG. 55.

mills for rolling metal tubes, with the object of reducing the diameter and drawing down the tubes while in a cold state, and without requiring that the metal shall be annealed after each operation. The machines are also employed for rolling tubes which have been drawn cold on a

mandrel, the object of such rolling being to release the tube from the mandrel.

Fig. 55 is an end elevation and fig. 56 a side elevation of a machine constructed in accordance with this invention.

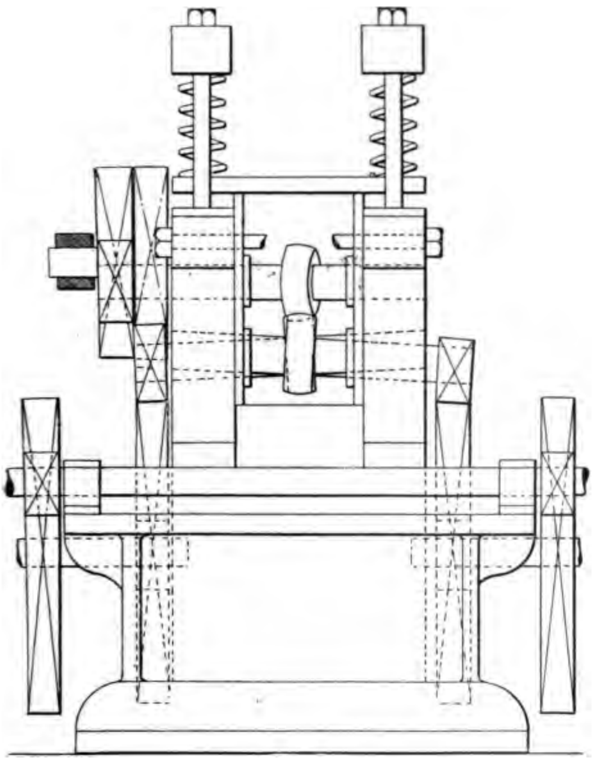


FIG. 56.

Three or more peculiarly-formed rolls are mounted within side frames or housings on spindles, which are arranged at an angle with each other. The working surfaces of the rolls are preferably in the form of bulbs or round-edged discs.

rolls in the mill. The adjustment is effected by the operation of steam-driven racks. The patent No. 2844, of 1883, became void in 1890, and the patent No. 12042, of 1887, became void in 1893.

The illustrations at figs. 61 to 64 inclusive are from Kellogg's specification No. 2933, of 1889. The inventor describes the object of his invention as follows: "It has been discovered that hollow steel ingots can be converted into seamless tubes, columns, and similar articles, by means of an organised machine composed of a series of pairs of positively-driven rolls and a tapered mandrel extended between the rolls, and that such articles can be manufactured

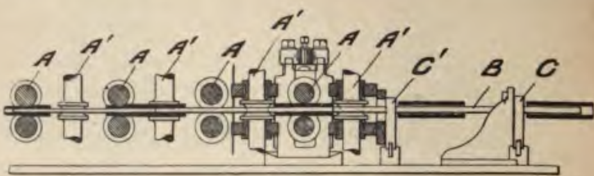


FIG. 61.

more rapidly by making the mandrel immovable, and arranging the supports or holders therefor so that the heated ingot can be passed over the supported end of the mandrel without changing the relation of the mandrel to the rolls."

The object of the invention is, first, to produce seamless tubes, &c., from hollow ingots by means of an organised machine, consisting of a series of pairs of suitably-shaped rolls, each successive pair of the series being driven at a greater speed than the preceding pair, and a tapered or conical mandrel placed between the series of rolls; second, to progressively roll and reduce a series of heated ingots into tubes or similar articles in the same machine, so that the several stages of the operation, from placing the heated ingot on the mandrel, the progressive rolling and reduction of a number of ingots, and the delivery of a completed tube off the end of the mandrel, may be carried on simultaneously and continuously; third, to support or hold a mandrel between a series of pairs of rolls, so that a heated ingot can

placed on the mandrel and fed to the rolls without entering the mandrel; fourth, to provide means for independently operating the grips by which the mandrel held; fifth, to provide means for cooling the mandrel without exposing the heated ingot to the cooling agent.

The adjoining fig. 61 is a sectional side elevation of the machine, showing the operation of feeding and reducing a

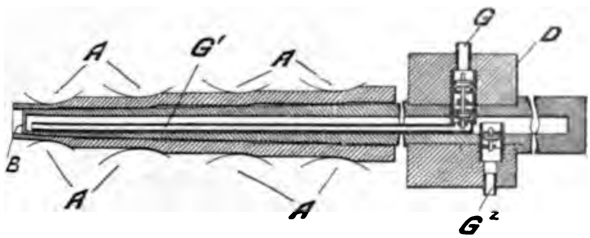


FIG. 62.

series of ingots simultaneously. Fig. 62 is a horizontal section to a larger scale through one of the grips, and longitudinally of the mandrel and of an ingot thereon, also showing means of controlling the flow of water into and out of the mandrel, and the gradual reduction of the ingot by the several pairs of rolls during the "pass" through the

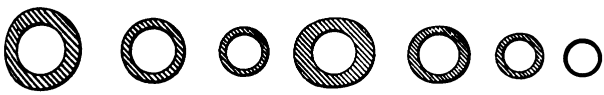


FIG. 63.

machine. Fig. 63 shows in cross-section the various forms given to the ingot by the successive pairs of rolls. Fig. 64 represents one of the grips in the open position and the means by which it is operated. The same reference letters in the different views indicate the same parts. A, A^1 indicate the rolls, which are arranged in pairs, and so disposed as to bring into alternate relation the horizontal rolls A and the vertical rolls A^1. The rolls are each provided with a peripheral groove of such shape in cross-section that

the grooves in the rolls of each pair form a cavity or "pass" of the same shape that the article is intended to receive from the rolls. The rolls of each pair are caused to rotate positively together in unison by suitable gearing. B is the mandrel, which is preferably made with a uniform taper commencing near the outer side of the first pair of rolls, and extending to the end, which rests between the last or discharging pair of rolls; it is also made hollow to facilitate cooling. The object of thus tapering the mandrel (which is clearly shown at fig. 62) is to facilitate the rolling action, the bind of the metal against the mandrel occurring only in the line of the bite of the rolls, the ingots being of larger internal diameter than the mandrel on both sides of this line. Hence the resistance to the drawing action of the rolls occurs only at the point of reduction; beyond this point, between the successive pairs of rolls, the ingot meets with no resistance to its progress from the mandrel, and the result is that the rolling can be performed more rapidly and with less power by using a tapered mandrel than with any other known form.

The ingot grips are placed in the positions C, C^1 at fig. 61, in front of the first pair of rolls. Each grip works independently, and is operated by its own mechanism. The group C^1 is placed as closely as possible to the first pair of rolls, but the grip C is far enough from the grip C^1 to permit of an ingot being placed in the mandrel between them, as shown at fig. 61. Each grip is formed from a pair of arms D, D^1, fig. 64, pivoted together by the pin E. The grips are opened and closed by a ram working in the cylinder F, under the action of steam, water, or other fluid pressure.

The cooling of the mandrel is effected by the circulation of water from the inlet G through the internal pipe G^1, fig. 62, and back through the annular space between the pipe and the internal surface of the mandrel to the outlet G^2. The outlet connections are formed in the jaws of the 't valves are arranged to prevent discharge of 'en the jaws are opened. This patent became

'on No. 8152, of 1890, Kellogg describes an ' use with the apparatus described in

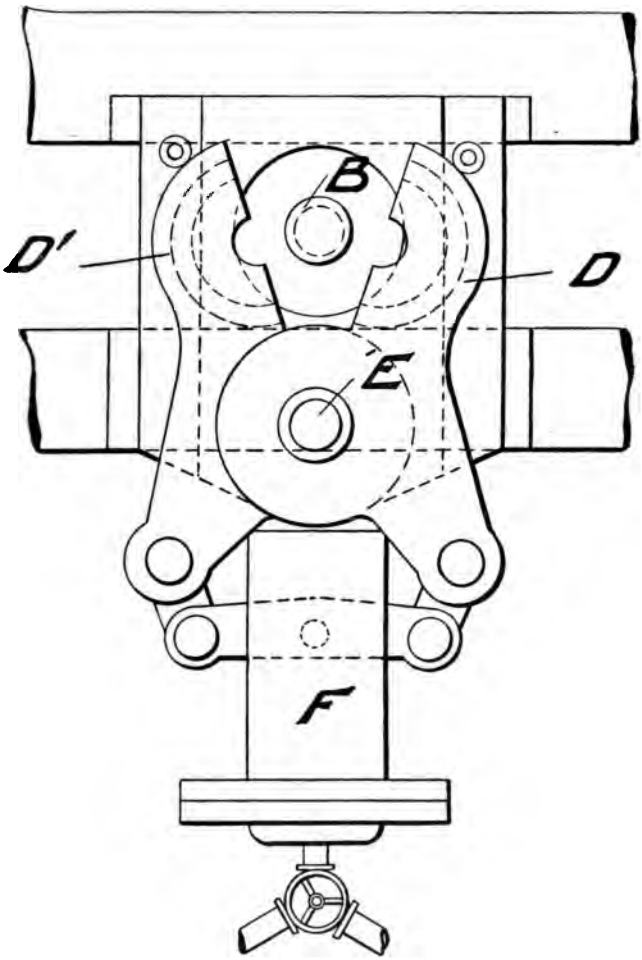


FIG. 64.

the aforesaid patent of 1889; and in his specificatio
16990, of 1890, further improvements on the 1889 m
are set forth. Both these patents became void in 189
On May 1st, 1888, S. P. Tasker, of Philadelphia, fil
British specification No. 6493, for "Rolling mills for m

FIG. 65. FIG. 67. FIG. 68.

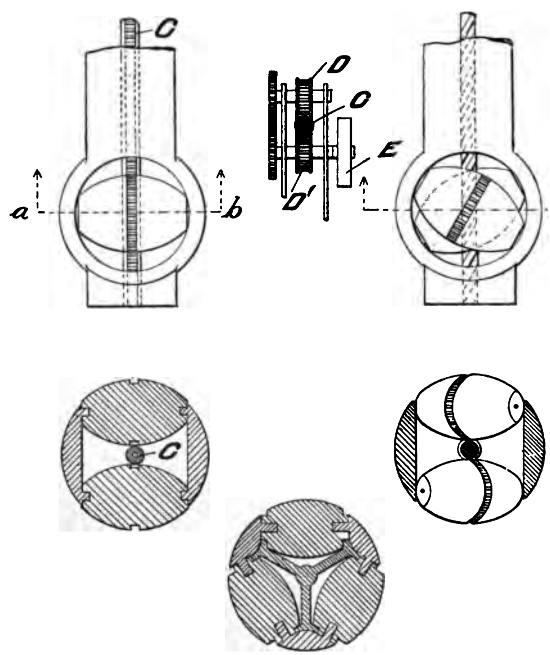


FIG. 66. FIG. 70. FIG. 69.

tubes from hollow metal ingots," in which he sets
that the object of his invention, broadly stated, is
manufacture of a tube from a hollow cylindriform
ingot (preferably a steel cast ingot) by the simult
subjection of the external surfaces of said ingot (eith
or cold) to the action of external compression rolls,

the internal surfaces of said ingot to the action of positively-driven rolls, which subserve also the office of a ball or mandrel proper, the result of the said subjection being not only the positive feeding of the ingot through the rolling mill constituted by the rolls referred to, but the compacting, consolidation, thinning, and reduction of the substance of the walls of the ingot, and its consequent extension or increase in length."

On the same date the same inventor filed an application which bears the next official number to the aforenamed specification, and in this specification, which is entitled "Roller mandrels," he describes means for effecting the

FIG. 71.

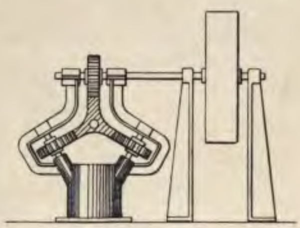


FIG. 73.

positive driving of the rolls mounted on the mandrels. The illustrations at figs. 65 to 73 inclusive are selected from the drawings accompanying this specification No. 6494, of 1888. The object of employing such rolls is, of course, to reduce the friction between the interior surface of the tube and the ball or head of the ordinary mandrel, and thus to permit of the more ready passage of the tube over the mandrel and withdrawal of the mandrel from the tube. Idle rolls had been previously employed by the inventor, and he refers to several prior United States patents for the better appreciation of this invention, of which the object "is to provide means for positively driving the mandrel rolls, so as to render them no longer idle rolls, the movement of which is wholly due to the movement of the tube upon them, but positively-driven rolls which move under the thrust or impulse of suitable actuating devices, with a positive rotative

motion, which is the same as, or greater, or less, than that of the tube operated upon."

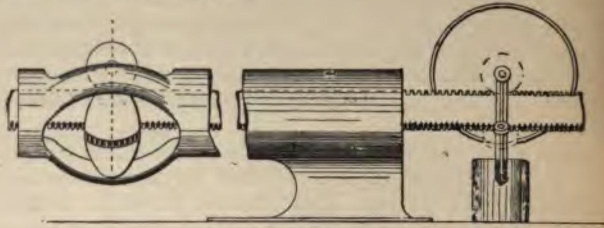


FIG. 72.

Fig. 65 is a top-plan view of a mandrel having two rolls, the axes of which lie in the same plane. Fig. 66 is a trans-

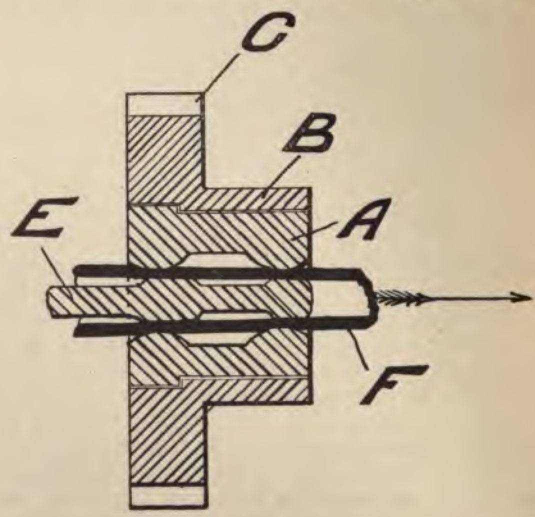


FIG. 74.

verse vertical sectional elevation through the mandrel of fig. 65 in the plane of the dotted line *a b* of said figure. Fig. 67 is an end elevation of a convenient form of operating mechanism

for the driving gearing of the mandrel rolls shown at figs. 65 and 66. Each roll is provided with sunken wheel teeth extending around the central circumference and which gear into the double rack C. The rack engages between two toothed wheels D, D', fig. 67, which are driven from the pulley E. Fig. 68 is a top-plan view of a mandrel having two rolls, the axes of which, although in parallel horizontal

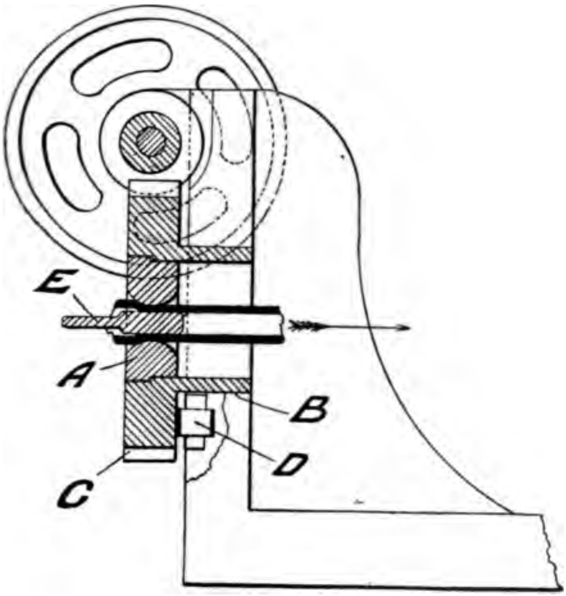


FIG. 75.

planes, are inclined to one another; and fig. 69 is a front elevation with part section. The double actuating rack in this case has teeth of a spiral form corresponding with the respective inclinations of the roll teeth.

Figs. 70 and 71 are transverse vertical sectional elevations through mandrels having three rolls, which are adapted to be actuated by driving gear constituted by racks of different

form, and figs. 72 and 73 a convenient arrangement of the driving mechanism. This patent became void in 1892.

A combination comprising a stationary mandrel with a revolving die is illustrated in figs. 74 and 75, prepared from the specification No. 9560, of 1884, of Joseph Short, of Birmingham, for "An improved apparatus for drawing tubes and bars." The machine, as illustrated, is for the purpose of "drawing, compressing, and reducing the diameters and

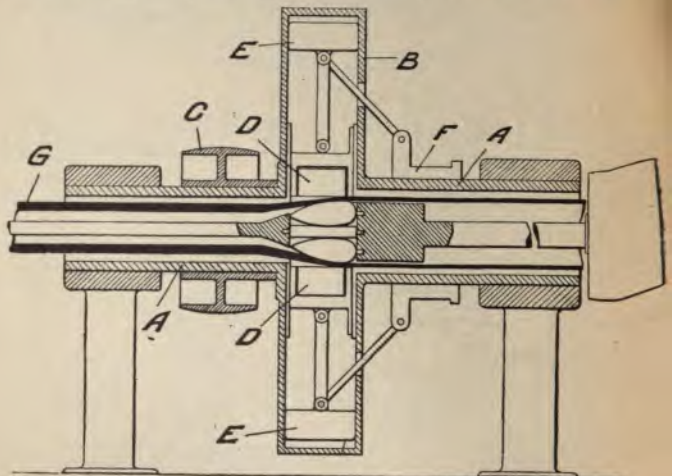


FIG. 76.

the thickness or substance of steel, iron, and other metallic tubes, bars, or shafting." The die A is keyed or otherwise secured within the socket B, formed with the worm wheel C. This wheel and socket revolve in the standard of the machine, friction rollers as D being arranged to receive the thrust during the drawing of the tubes. The mandrel E is stationary, but the tube F has a longitudinal movement imparted to it in the direction of the arrow as the die is revolved. The die A may be provided with two or more bulbs, and thus two or more drawing operations may be effected simultaneously. This patent became void in 1894.

In the specification No. 10796, of 1887, of Edward Cope and Alfred Hollings, of Manchester, there is described a machine for expanding steel tubes by subjecting the metal to a rolling or squeezing action around its longitudinal axis, with a revolving tube expander on the interior, and revolving rolls on the exterior of the tube. Fig. 76 is a vertical section, and fig. 77 an end view of the machine.

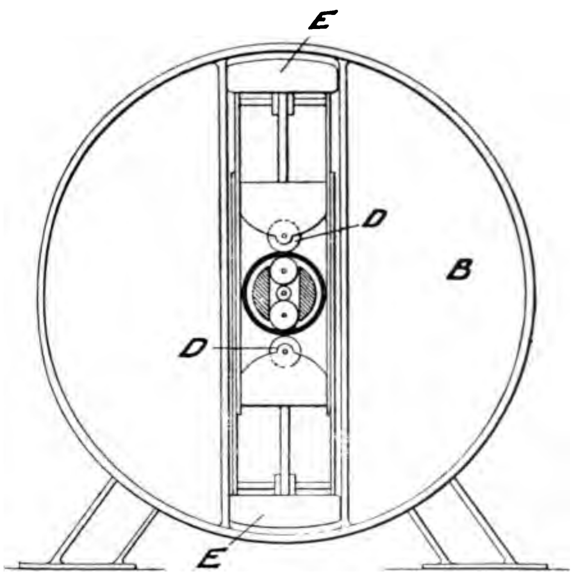


FIG. 77.

sleeve A, with central cheeks B, is mounted in bearings, driven through the pulley C. The outside rollers D are ied in bearings free to slide to and from the centre of sleeve, and such bearings are connected by rods to hts E, the bearings on the one side being connected to weight on the opposite side of the sleeve. The weights also connected to the sliding collar F in order that they be adjusted if necessary. The expanding mandrel on

the interior of the tube G is fitted with rollers as illustrated. The centrifugal action of the weights E of the external rolls D cause the said rolls to act on the outside of the tube, and by the combined action on the inner and outer surfaces the internal and external diameters of the tube will be increased without material elongation.

CHAPTER VII.

Robertson Processes. Ehrhardt Processes.

James Robertson (the inventor of the frictional gearing bearing his name) has obtained several patents relating to the manufacture of seamless steel and other tubes. His specification No. 5018, of 1888, describes the production of seamless metal tubes from billets of metal in a hot or viscid state, by the "squirting" of the metal through a die and over a mandrel. Mr. Robertson states in his specification that it is no part of his invention to use any of his "new and improved modes and means or apparatus for making tubes out of what are usually designated soft metals such as lead and tin." The apparatus consists primarily of a fixed die and a mandrel. The billet is placed in the die and whilst therein a mandrel is forced through the centre of it. The die is so shaped that the metal is not forced through it by the action of the mandrel, but is squirted back over the mandrel; thus the mandrel and the tube move in reverse directions. For the purpose of preventing the metal from being forced through the die in advance of the mandrel, a holding-up or regulating hydraulic stem is employed to retain the metal in the die whilst it is submitted to the action of the mandrel. The dies are sometimes made in segments, and two mandrels may be employed; various other modifications are described in the specification and illustrated by drawings. Revolving dies may be employed and arrangements made for the application of a centrifugal force to the mass of metal to be operated upon.

Robertson's specification No. 1627, 1890, sets forth an invention which is described as consisting chiefly of a further development of that described in the previously named specification (No. 5018, of 1888), the development consisting "mainly in new and improved means and apparatus for operating, piercing, and drawing tube

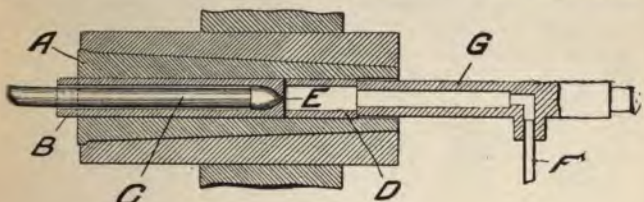


Fig. 78.

mandrels and dies on billets or tube blanks, made soft by heat, and placed in long tube dies having forming bores or seats in conjunction with a holding-up stem." The chief feature of the invention is the use of a *sliding die* in combination with a mandrel and holding-up stem, the mandrel being forced into the billet in one direction, thus causing, in conjunction with the holding-up stem, the metal

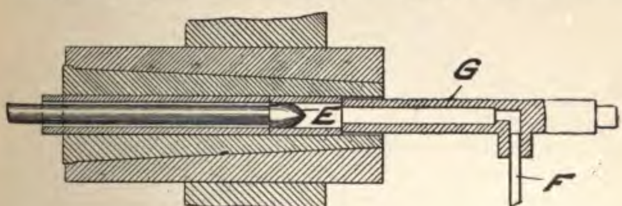


Fig. 79.

to be squirted out in the opposite direction. The object of the sliding die is to "relieve the mandrel from being packed or stuck up in the metal, and render it easily practicable to form a solid billet of metal into a tube, or to draw out a tube blank in this way." The sliding movement of the die is effected in several ways, the simplest being to

allow the die, under its frictional contact with the tube or metal, to travel with such tube in a direction opposite to that of the mandrel. This patent is still in force.

The illustrations from figs. 78 to 83 are from Robertson's specification No. 11436, of 1891. This invention is described as consisting mainly in new and improved means and apparatus for fixing and operating the dies, matrices, mandrels and metal billets during the shaping operation, and new and improved means and apparatus for expelling the articles so formed, and also for quickly cooling the

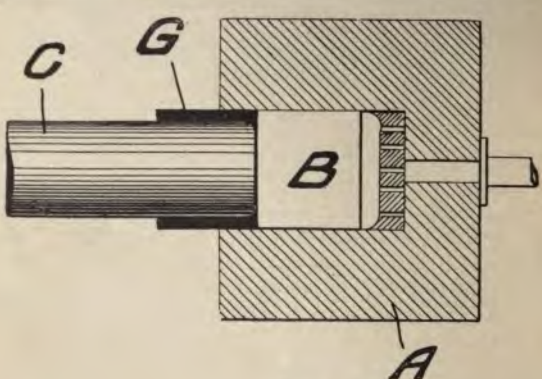


FIG. 80.

matrices, dies, mandrels, or shaping tools by injecting water or other fluid at a high pressure. The apparatus in its primary form comprises a die, a piercing mandrel, and a holding-up stem or ram, such as described in the previous specification, the billet to be operated upon being interposed between the mandrel and the holding-up stem. The holding-up stem itself is not in direct contact with the billet, a holding-up ferrule being disposed between the stem and the billet for receiving the mandrel after it is forced through the billet. A "service plate" is placed over the billet end of the holding-up stem; such plate offers sufficient resistance to the pressure of the metal under the action of the mandrel to prevent it from flowing into the

ferrule, but will give way or be shorn through when the mandrel reaches the end of the billet. In the sectional plan at fig. 78, A is the die (made in two halves), and B the billet shown nearly pierced through by the mandrel C. D is the

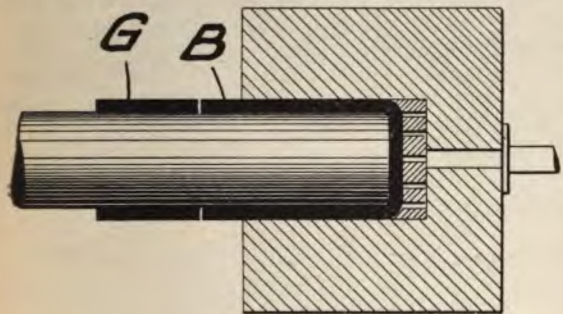


FIG. 81.

holding-up ferrule piece and E the service plate. Fig. 79 shows the position of the mandrel after it has been wholly forced through the billet, with the service plate E shorn away; at this position the piercing operation of the

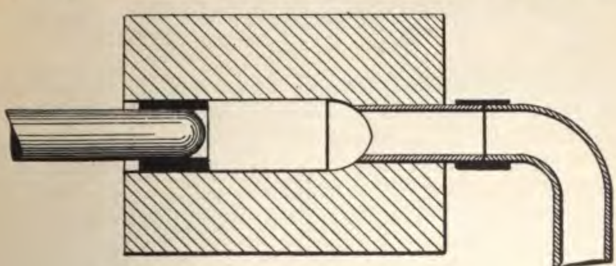


FIG. 82.

mandrel is completed, and its forward motion stopped. The cooling of the tools and the expulsion of the tube is effected by admitting water at a high pressure through the connection F in the after-holding stem G.

In the arrangement indicated at fig. 80 a billet of hot metal is shown in the die A, and a mandrel C inserted in same held centrally on the hot metal by the guide G, all in a state ready for the forcing of the mandrel into the billet. Fig. 81 illustrates the completion of the stroke of the mandrel. Figs. 82 and 83 represent another modification. This patent is still in force.

James Robertson's specification No. 19356, of 1893, describes an invention which "relates mainly to the drawing of metal rods, bars, tubes, wires, &c., through dies, in a cold state, and consists mainly in placing such rods, tubes, or the like, in a closed vessel or container, and pressing, lubricating, and propelling them through dies or shaping and drawing

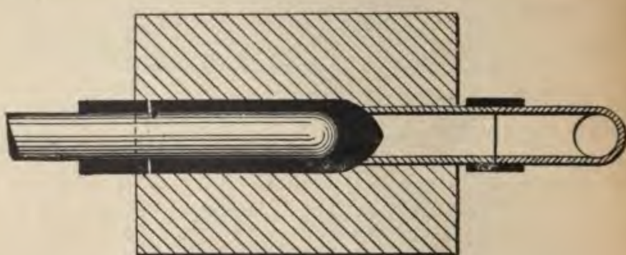


FIG. 83.

tools, by the direct contact of a liquid in motion and under a degree of pressure." Various modifications of such improved hydraulic machines are set forth in the specification. The inventor also states that it is a part of his invention "to use the propelling liquid at such a degree of pressure above the resisting strength to crushing action of the metal articles being operated upon, as to become what I shall term a hydraulic die suited for compressing, drawing, and treating metal tubes, tubular and hollow articles, rods, bars, wires, and plates. Unless in conjunction with steel or very hard dies, or with mandrels, this hydraulic die has little tendency to smooth or improve the uniformity of the diameter of the tube blank operated upon, but has a greater tendency than an ordinary die to improve the uniformity of thickness

or gauge of a tube subjected to its action circumferentially." "There is not much drawing or pressing effect obtainable from a hydraulic die unless the propelling or surrounding liquid is used at about one-half greater pressure than is required to partially crush the metal it is made to surround and draw. Take, for example, the most prominent metal to be dealt with in drawing tubes, which is steel, the crushing weight of which is, say, 20 tons per square inch, then one-half more margin of pressure to produce the requisite compressing, squirting, or drawing effect; or, say, 30 tons per square inch. This great end pressure in a die of

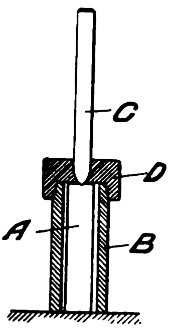


FIG. 34.

large internal cross area produces more end pressure than the best ordinary steel dies are usually found to stand against abrasion and expansion; but take a die of only $1\frac{1}{8}$ in. internal diameter, which is equal only to one square inch, and when placed in a suitable container (as described in the specification) with the propelling liquid, used at the necessary drawing pressure of 30 tons per square inch, the propelling effect on end is only 30 tons, or just about the requisite degree of force that this size of ordinary steel drawing die will stand." This patent is still in force.

The Ehrhardt process of manufacturing weldless steel tubes has received considerable attention from manufacturers and others interested in the production of steel tubes, and at the time of writing (in the year 1897) the public are invited

to subscribe to a company termed the Universal Weldless Steel Tubes Company (Ehrhardt's Process) Limited, formed for the purpose of manufacturing in the United Kingdom weldless steel tubes by the Ehrhardt process with special machines to be supplied by Ehrhardt. The prospectus states that the process is for the "manufacture of weldless tubes for marine and all other water-tube boilers, weldless

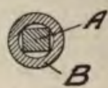


FIG. 85.

FIG. 87.

tubes for steam, gas, and hydraulic pipes, cycle tubes, and all tubes of a variety of sizes and sections, and other hollow forged articles." It is also stated that Sir W. Armstrong, Whitworth, and Co. Limited have purchased the exclusive right to use Ehrhardt's process in the manufacture of gun liners, shells and other war materials.

In 1891 Henrich Ehrhardt, of Düsseldorf, Germany, filed his specification No. 3116, of 1891, for "Improvements in forging and shaping iron and steel blocks," described as an

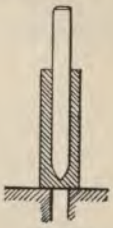


FIG. 86.

invention relating to "a new method of simultaneously punching and shaping iron and steel blocks in red-hot or white glowing state." The illustrations, figs. 84 to 91 inclusive, are from the drawings accompanying the specification. "To produce a hollow cylinder from wrought iron or steel, a piece of square iron or steel is taken, the cross-section of which, diagonally measured, corresponds to the diameter of

the hollow cylinder to be produced. The said piece of square iron or steel A, when in a red-hot or white glowing state, is delivered into the matrix B, the inner space of which also corresponds to the shape of the hollow cylinder to be produced, and a pointed core bar C is then driven into the metal by means of a hammer or press, whilst the lid D is

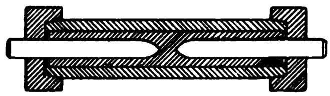


FIG. 88.

used as a guide for the said core bar. The diameter of the latter is chosen so that the material forced aside by it is sufficient to fill the four segment-shaped spaces between the square sides of the block and the interior surface of the matrix. The core bar enters the metal without any difficulty, as the metal whilst being forced away can give way at its sides, and a hollow cylinder with closed bottom, as represented at figs. 86 and 87, is produced."

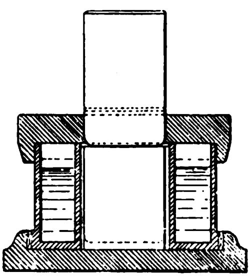


FIG. 89.

"For manufacturing hollow bodies of somewhat greater length, two core bars instead of one may be employed, and they may be pressed into the metal from both sides as illustrated at fig. 88."

"Blocks of irregular sections may be punched and shaped in quite the same way, there being, however, the condition that the piece of metal be centred by the matrix, and that

sufficient space be left for receiving the material pressed away by said core bar or bars. The latter may be of any regular or irregular cross-section, for instance, of oval shape, as shown in figs. 89, 90, and 91."

"For better securing the guiding and contact of the metal piece, and for furthering the swell of its free surfaces, those parts of the matrix which are touched by the edges of the metal piece may be provided with a cooling device." Thus in figs. 89, 90, and 91 spaces for containing water are provided as illustrated. This patent is in force.

Ehrdardt's specification No. 7497, of 1892, is for a "Process and apparatus for the manufacture of tubular bodies." In the opening clause of this specification the

FIG. 90.

FIG. 91.

inventor states: "In the specification to patent 3116, of 1891, was described a process for the manufacture of hollow bodies, according to which heated iron or steel bars had a longitudinal passage formed through them by means of a die and mandrel." The patentee then states that "according to one part of the present invention, in order to prevent in the said process the metal blank operated upon from being compressed longitudinally by the driving in of the mandrel, the arrangement shown at the figs. 92 to 95 inclusive is employed." "A is the perforating and pressing mandrel of circular cross-section; B is a die with a cylindrical cavity; and C the rod or blank to be operated upon, which is of a square cross-section. D, in figs. 92 and 93, is a preparatory pressing mandrel, which, as shown at fig. 93, forms a collar on the end of the heated blank. The prepa[illegible] mandrel

emoved after the formation of such collar, and the blank
ı has a hole formed through it by the mandrel A, as
wn at figs. 94 and 95, while at the same time it is pressed
the die B so as to assume its configuration. During
operation the collar previously formed prevents any
ısing together in the longitudinal direction of the formed
e, as in the first instance it takes an abutment on the
er end of the die, and during the finishing of the
ration it is gradually drawn into the die by the pressure

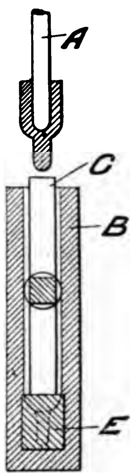


FIG. 92.

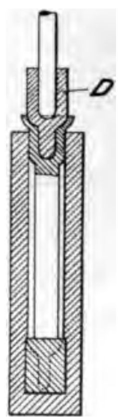


FIG. 93.

he mandrel, as shown at fig. 95. At the lower end of the
is a sliding block E, which, in the position shown at figs.
ınd 93 when the preliminary mandrel is operating, serves
a support to the lower end of the blank. After this
ration the sliding block is pushed forward until a recess
ırmed therein is situated under the hole of the die. The
ss F serves to form a nipple on the end of the tubular
y during the finishing operation (as shown at fig. 95),
ch nipple is required for the further treatment of the
ılar body."

"As shown in fig. 92 the circular hollow of the die constitutes the circumscribed circle of the rectangular section of the blank, so that the die brings the blank at once into the central position when it is inserted. The cross-section of the mandrel or plunger is made of such a size that the material of the blank which it displaces when forced in fills out the spaces left between the rectangular sides of the blank and the circular wall of the die. On pressing, such an amount of friction is produced against the walls of the die that only a slight longitudinal compression is effected even when the above-described collar is not made to bear against the die. The friction against the walls of the die can be increased by roughing it with file cuts or by forming grooves therein; but the die would then require to be divided longitudinally in order to remove the finished article."

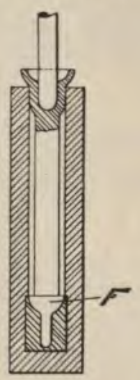


Fig. 94.

Fig. 95.

Tubular bodies can also be formed out of bars or blanks of a circular section; the process is described and illustrated in the specification.

"In the foregoing description the production of the hollow body by the driving in of a mandrel has been described. Such driving in of the mandrel can, however, be utilised when using suitable devices therewith for producing a simultaneous rolling and drawing of the tubular body. Fig.

96 is a sectional plan illustrating the apparatus for carrying out this extended process. The mandrel G, having the same cross-section as that of the blank to be operated upon, is connected to the piston or plunger of a hydraulic press. The blank H which has been introduced into the die K is conveyed by the mandrel G to the die L, into which projects

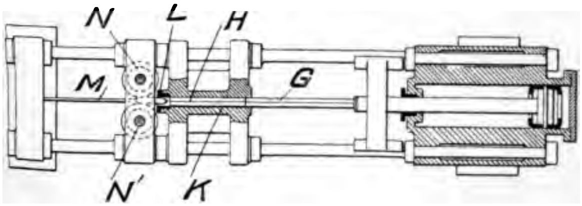


FIG. 96.

the mandrel M, towards the rollers N N^1. If, therefore, after the perforation has commenced in the die L K, the blank is forced farther forward by the plunger G, it will be fed over the mandrel M towards the rollers N N^1, and these being at the same time rotated by suitable gearing at a

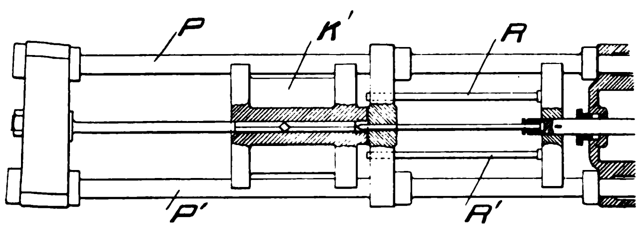


FIG. 97.

quicker surface speed than that of the plunger G, they will exercise a drawing action on the blank H. The rollers N N^1 are driven and their speed regulated by spur gearing, which is rotated by means of toothed racks actuated by the piston of the hydraulic cylinder. Thus it will be seen that by a continued pressing and drawing operation the object acted upon is simultaneously perforated, drawn, and rolled."

Fig. 97 illustrates another construction of apparatus for producing hollow bodies. In this modification the die K^1 is

caused to slide along the tie rods P P^1, and thus at the
pletion of the pressing operation the perforated artic
be situated outside the die. The movement of the
produced by the advance of the rods R R^1, secured t
crosshead of the piston or plunger rod.

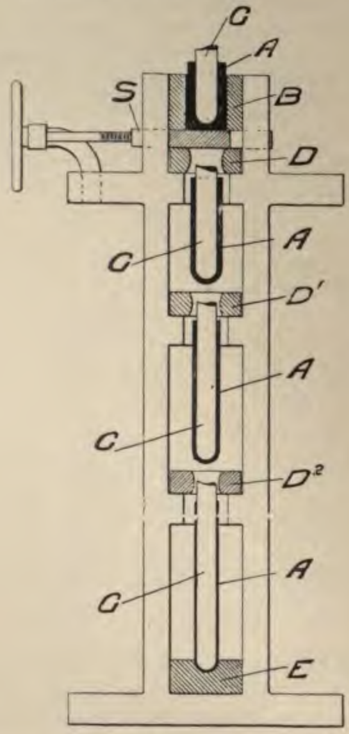


Fig. 98.

Fig. 98 is a longitudinal section of an apparat
drawing to the required section immediately afte
formation of the hollow body and during the same
The heated iron or steel bar, or blank, is placed i

die B, and is there perforated in the described manner. The bottom of the die is formed by a slide S, which is moved in the die B by a screw spindle and hand wheel, or by other suitable means. Below the die are situated, in the same axial line, draw rings, as D D^1, D^2, of gradually decreasing diameter. The apparatus works as follows: After the die B has been closed at the bottom by the screw S, the metal blank A in the die is perforated as described. When the mandrel C, which is actuated by a hydraulic cylinder or other suitable means, has been forced to the required depth into the material, the pressure on the mandrel is reduced, in order to enable the slide S to be withdrawn. After such withdrawal of the slide, the mandrel C is moved downward together with the tubular body, and passes together with the latter successively through the drawing rings D D^1, D^2 until the tubular body has acquired the requisite thickness. Below the last ring is placed a block E, with a suitable hollow for imparting to the end of the body, in the event of this requiring to be closed, the requisite configuration by compressing the same between the said hollow of the block E and correspondingly formed end of the mandrel C. This patent is in force.

Later particulars relating to Robertson and Ehrhardt processes will be found in Chapter VIII. of this edition.

CHAPTER VIII.

The Piercing of Solid Steel Billets.

The manufacturer of seamless brass and like tubes has not to encounter the trouble experienced by the manufacturer of steel tubes in the initial conversion of a solid into a hollow body. Working with a metal of which a chief characteristic is its facility for the production of thoroughly sound castings, the brass tube manufacturer has but to cast a number of shells, or short thick tubes or cylinders, and proceed by rolling and drawing operations to extend them in length

and reduce them in thickness to form tubes of the required dimensions. The steel tube manufacturer is unable to produce the shells or hollow blooms which constitute his embryonic tubes in so ready and convenient a manner.

To obtain weldless steel tubes suitable for use in water tube or tubulous boilers, in the construction of cycle frames, and for other services the manufacturer must perforce start his operations upon a solid billet produced by the subjection of the original cast ingot to carefully conducted forging or rolling operations. The formation of the initial bore whereby the solid billet is converted into a hollow bloom presents difficulties that have attracted the attention of many inventors. To drill right through the billet either from end to end, or from both ends by tools working towards each other, is a slow and expensive process and involves waste of metal. But it has been urged, and with considerable reason, that as there is a generally recognised advantage in removing a considerable amount of the top or dead head of an ingot or casting, so also, as, in the words of Mr. Alex. E. Tucker, F.I.C., of Birmingham, the "chemical defects, cracks, and segregated impurities tend towards the middle and top of an ingot, the advantage obtained by drilling out the centre of the rolled bloom (billet) will be apparent. The result of drifting, punching, or spinning out a hole instead of drilling it out of the bloom (billet), in which latter case alone the core is removed, must be a higher percentage of defectives, at all events on the inside surfaces, than when such core is taken out."

In some billet piercing processes, of which the Mannesmann and Stiefel are well known instances, the billet, by means of rolls or discs, is rapidly rotated and simultaneously forced on to and over a mandrel, whereby it is pierced from end to [illegible] the metal displaced from the centre serving to increase [illegible]ngth of the resultant bloom, tube use, or shell. The [illegible] the 1885 Mannesmann British patent (No. 1,167), [illegible]at the end of the full 14 years' term in the year [illegible] the 1886 patent (No. 9,939)—which is described [illegible]rovement on the former patent or patented in[illegible]e year 1900. In the original specification of [illegible]t R. and M. Mannesmann stated that their

process consisted "mainly in working upon the outside of a solid blank by external rolls or rollers in such a manner that the blank assumes a tubular shape, either no core or mandrel being employed in such cases, or else a core or mandrel being employed for the purpose of smoothing the inside of the pipe or tube thus formed, reducing the thickness of its sides or shell and enlarging its internal diameter." In the drawings accompanying their specification they give illustrations showing how by their process they could roll an axle so that it should be hollow throughout the greater part of its length but solid at the ends and also, if desired, at intermediate parts. But it was difficult to understand that the process could be relied upon to produce such axles, and that tubes could be produced on a useful or commercial scale without the employment of a piercing mandrel. In 1898, about two years before the expiration of the aforesaid British patent, steel tube manufacturers throughout the country were much interested in the formal application of the proprietors for leave (which was granted) to amend their specification by striking out the statement concerning the production of tubes without the employment of a core or mandrel, and by abandoning the greater portion of the drawings, including those of the hollow axles, and deleting the descriptive matter and claims relating thereto.

Since his well known patent No. 23,702, of 1895, R. C. Stiefel has filed applications and obtained patents for other inventions relating to the piercing of solid ingots, billets or blanks. The adjoining illustration, fig. 99, is from his specification No. 30,449, of 1897, setting forth an invention of which the object is stated as the piercing of solid blanks or billets longitudinally "by passing them endwise between rolling surfaces and over the point of a mandrel lying in the pass between them, the rolling surfaces compressing and slightly reducing the diameter of the blanks without twisting or disturbing the longitudinal arrangement of their fibres and without there being any slip between the rolling surfaces and those portions of the blanks with which they come into contact."

The conical rolls A and B rotate in the same direction as indicated by the arrows thereon; their axes and the lines of

their working sides all converge towards and intersect a common point C on the axial line of the pass. The rolls in the example shown by fig. 99 impart only a rotary motion to the billet D, the endwise movement, whereby the billet is forced on to and over the piercing mandrel, is imparted by a hydraulic ram E or by other means. The patentee says:—"If the rolls were cylindrical or of uniform diameter they would of necessity impart a higher speed of rotation to that portion of the billet within their grip which has the smaller diameter, than to the portion having the larger diameter; and this would result in a twisting of the billet. With my conical rolls arranged as

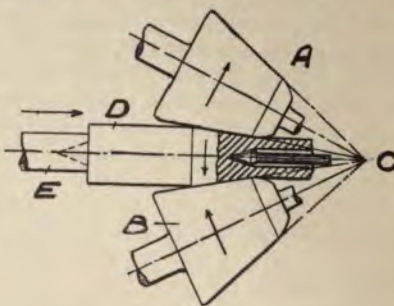


Fig. 99.

shown, there is absolutely no twist imparted by the rolls to the billet, and no slip between the contracting surfaces of the rolls and the billet, for while the converging sides of the pass cause a gradual diminishing of the diameter of the billet it will be observed that the diameters of the rolls diminish progressively in the same ratio as the diameters of the billet decrease, the larger diameter of the billet being gripped by large diameters of the rolls, whilst the smaller diameters of the billet are gripped by proportionately smaller diameters of the rolls, so that an absolutely uniform speed of rotation is imparted to every portion of the billet within the grip of the rolls. This I regard as a most important feature of my invention, and it is the result of causing the

axes of both rolls and the lines of their working surfaces to converge to a common point on the axial line of the pass. So far as I am aware, this has never been done before, and I know of no device with rolls having a tapering or converging pass between them in which there is not some twist imparted to the billet, or some slip between the billet and the working faces of the rolls or both."

In the example shown at fig. 100 "the rolls are oppositely inclined relatively to the axis of the pass, so that the rolls themselves will cause the endwise movement of the billet

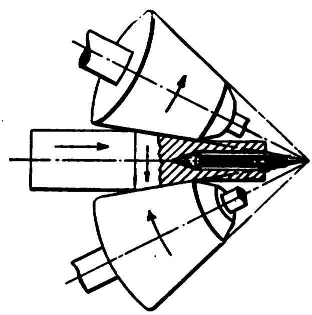


FIG. 100.

without the aid of a hydraulic ram or other mechanical appliance to force the billet through the pass and over the head of the mandrel."

In Stiefel's specification, No. 611, of 1898, discs are employed instead of the rolls described in the aforesaid specification of 1897.

Concurrently with the 1897 specification of Stiefel, a specification of another inventor (J. A. Charnock) was passing through the British Patent Office. Charnock's application was filed before that of Stiefel, and is numbered 14001 of the year 1897. Fig. 101 is from one of the illustrations accompanying Charnock's specification, the opening clause of which is as follows:—"This invention relates to apparatus for rolling tubes of the kind described in the specification of letters patent granted to Ralph Charles

Stiefel, No. 23702, of 1895, and has for its object to roll or draw out metallic ingots or blanks in a heated state without subjecting the metal to torsional strain or materially disturbing the longitudinal arrangement of the fibres. The mechanism comprises a pair of rolls or a roll and a disc working in conjunction with a mandrel located in the pass between the rolls or between the disc and the roll."

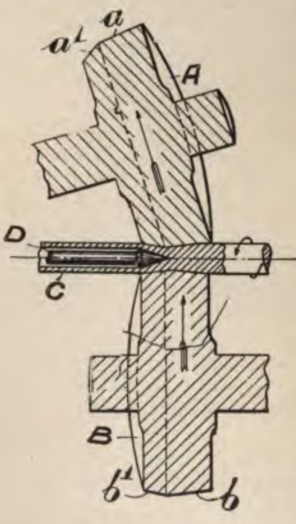


FIG. 101.

The rolls A and B, which are driven in the direction indicated by the arrows, each have two peripheral working surfaces, a a' and b b' respectively, in the form of frustra of cones. "In the case of the roll B the two frustra forming the working surfaces b b' have a common base, and the ices of the cones would lie one on each side of the roll. the roll A, however, the smaller diameter of the frustrum d by the working surface a constitutes the larger r of the other frustrum formed by the working that is to say, the apices of both cones would lie

on one side of the roll." The motion of the billet C is both rotary and longitudinal, since the rolls A and B revolve in the same direction and have their axes set at such angles to the axis of the pass that the billet is fed forward by the rolls, which grip it firmly owing to the tapering of the pass. "The length of the surfaces *a'* and *b'* is preferably equal to, or slightly greater than, the length of the conical portion of the mandrel D, and these surfaces are so shaped relatively to

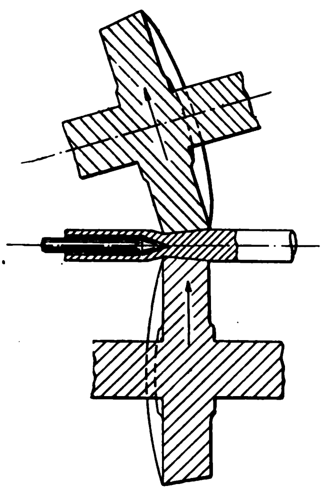


FIG. 102.

this part that they continue to act upon the billet C after it has been pierced, thus smoothing or finishing the tube before it leaves the pass." When it is "not absolutely necessary to finish the tube after it has been pierced by the mandrel, a comparatively rough tube being sufficient," each roll may have but one working surface. Fig. 102 is an example of such a modification.

The mandrel may be positively rotated or left free to be rotated by the tube passing over it.

Another arrangement, comprising a bevelled edge disc, working in conjunction with conical rolls for piercing solid billets without distorting the fibre of the metal, is set forth in the specification No. 8148 of 1898, of J. C. Sturgeon, of Erie, Pennsylvania, U.S.A. The patent is now void.

For the same object another American inventor, L. D. Davis, also of Erie, Pa., describes in his specification, No. 12828, of 1899, an arrangement of a pair of discs with the piercing mandrel between them, the axes of the discs being respectively above and below the line of travel of the ingot.

In his specification No. 9144, of 1898, W. Pilkington, of Birmingham, describes the piercing of solid steel or other billets by the application of an explosive force behind a piston directly connected with the piercing mandrel. The patent is now void.

The specification No. 14562, of 1897 (T. B. Sharp and F. Billing, of Birmingham), describes the piercing of billets "by a series of pressures, blows, or impacts." The hot billet is placed in a cylinder, and is therein subjected to the action of a piercing bar or mandrel, to which a reciprocatory movement is imparted through the medium of an eccentric, or a system of toggle joints. The patent is now void.

One of the best known patents of the late James Robertson, relating to the piercing of solid-steel billets, is No. 11436, of 1891. A leading feature in the specification of this patent is what is described as a "service plate," which is placed over the mouth of the holding-up stem, or the ferrule, in advance of such stem. As the mandrel is forced by hydraulic pressure into the billet the metal flows back over the mandrel, and so forms the tube. The service plate, during the greater part of the piercing operation, is required to prevent the metal from flowing into the ferrule or holding-up stem, but towards the completion of the operation it is shorn through by the advancing mandrel. The patent is now owned by Messrs. Tubes Limited, of Birmingham, who brought an action against another firm of steel tube makers for infringement of the patent by using a "service plate" as and for the purpose above described. The litigation extended over several years. At the trial the

patent was held to be valid, and judgment given in favour of the plaintiffs. On appeal by the defendants this decision was reversed, but on a final appeal to the House of Lords by the plaintiffs the original judgment in favour of the patent was restored on November 20th, 1902.

The formation of tubes or tubular bodies by causing the metal to flow back over the advancing mandrel or punch is also to be found in the specifications No. 15594, of 1899, and 21052, and 21053, of 1900, of S. Frank, of Frankfort-on-the-Main, Germany; and in the specification No. 1064, of 1896, of R. Bungeroth, of Remscheid, Germany. In the last-named specification (the patent granted on which is in force), we find instead of a "service plate," such as patented by Robertson, that a bar is held up against the end of the billet until the nose of the piercing mandrel is near such end; the bar is then allowed to yield, so that the end piece of the billet may be punched out.

It is found, as might be anticipated, that the metal at the end of a billet subjected to the action of a bar or mandrel, which pierces right through such end, is more liable to defects than at any other part. The tendency of defects and impurities in the metal to tend towards the middle of an ingot or billet has been previously referred to, and it can be well understood that the advance of a bar or mandrel through a hot billet would have the effect of driving such impurities in advance of it, so that although some of them would flow back over the mandrel with what may be termed the main stream of the metal, there would be an accumulation at the rear end of the billet. It is found to be more economical in many cases to treat such end piece of the core or central part of the billet as waste than to include it in the bloom.

When the metal is to be subjected to considerable extending processes by subsequent rolling and cold drawing, great care is necessary that defects shall be avoided which, in the bloom itself appear (if indeed they appear at all) to be of little if any consequence. A minute fissure, resulting from a tiny bubble in the molten metal or from some other cause, and presenting itself merely as a short hair line on the surface of the bloom or pierced billet, may split a considerable length

of tubing during cold drawing. Such "rokes" (as tube makers term them), are particularly productive of "scrap" in drawing small gauge tubing, such as is employed in cycle construction.

The illustrations, figs. 103 and 104, are from the specification No. 10878, of 1901, of G. Evans and Tubes Limited, of

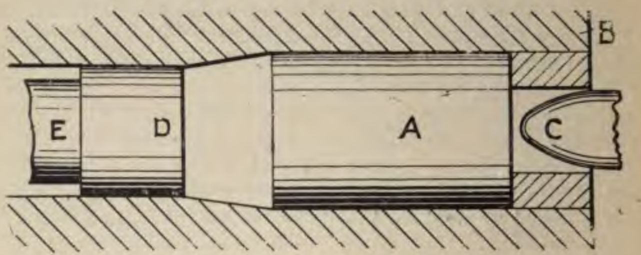


FIG. 103.

Birmingham, covering "a process of piercing solid steel or other billets for the manufacture of tubes, ordnance shells, and other like hollow bodies, in which, whilst the outer part

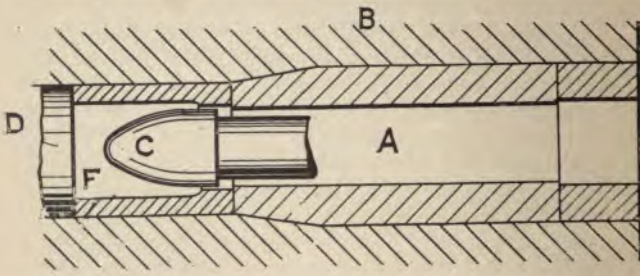


FIG. 104.

of the billet is prevented from movement, its core or inner part is displaced and utilised to form an extension on one end of the billet."

Fig. 103 illustrates the apparatus employed in accordance with the aforesaid invention for the piercing of a shell from

a solid billet. The billet A is completely inserted "in a fixed or moveable die or holder as B, mounted upon a suitable machine, which imparts the required motion to the said die, or to the piercing bar C, or to both die and bar as may be required." To prevent endwise movement of the billet, as a whole, the die is tapered beyond the inner end of the billet, as shown in the drawing, so that it shall form "an annular abutment, with a decreasing space beyond." "Thus, when the billet A is forced or drawn against the piercing bar or mandrel. or the latter is forced into the former, no movement either in a forward or backward direction is imparted to the billet as a whole, relatively to its die or holder B, but the core of the metal is forced under the action of the piercing bar into the tapered die space hereinbefore referred to. If, therefore, the solid billet A is, say, 6 in. diameter by 9 in. long, it will—after being pierced . . . . by a bar or mandrel described—have a total length of about 12½ in., made up of the original 9 in. parallel, part 6 in. diameter, together with the taper part formed by the metal pushed or drawn out from the centre of the billet into the supplementary reducing die space. There is no movement of the skin or surface of the billet over the surface of the die during our piercing process. The metal is simply forced from the centre of the billet, and entirely disposed in the taper die extension beyond the original inner end of the billet."

"In the piercing of billets for the manufacture of shells the piercing bar is not forced through the inner end of the metal, but a solid portion is left of the required thickness at the nose or extremity of the tapered part, forced out from the centre of the billet. The said solid portion of metal is consolidated by its abutment against a loose end or closing piece, such as the ram head D, arranged at the narrow extremity of the tapered die part. By means of the ram E, at the rear of the said closing piece or head D, which is operated in any convenient manner, the shell can be forced out from the die at the conclusion of the piercing process."

"But in the piercing of billets for the manufacture of tubes the piercing action is continued until the forward end

of the bar or mandrel has passed right through the billet, which is thus entirely converted into a tubular form (as shown at fig. 104) without any waste of metal. In this case a hollow sleeve or bush, as F, is disposed between the end of the tapered die space and the ram head D to receive the piercing bar or mandrel C."

The Ehrhardt process for the formation of hollow blooms from solid steel billets appears to be much more extensively applied in Germany than in this country. We have probably not yet heard the last word concerning the purchase by the British Government, from a German firm, of a number of field guns made under the Ehrhardt system, though much has been said and written on the subject by all sorts and conditions of men. There has been plenty of noise if little knowledge.

Under the Ehrhardt process a hot billet of a square or angular section is placed completely within a matrix or die of the section of the hollow bloom to be produced; the angular edges of the billet may touch the sides of the die when placed therein, but sufficient space must be provided between the sides of the billet and the die to permit of the lateral displacement of the metal during piercing. With the inner end of the billet supported by the adjacent end of the die, against which it abuts, a piercing bar or mandrel is then forced into the centre of the metal; the displacing action causes the sides of the billet to swell out to the sides of the die.

The illustration at fig. 105 is from the specification No. 30358, of 1897, of E. L. Cooper, for "Improvements in ingot piercing methods and appliances." The patent on the specification became void in the year 1901. The invention is described as relating to "improved methods of and means for piercing copper and steel ingots while hot, and has for its object the piercing of such ingots without the use of dies for enclosing the ingots during the operation. Such dies restrict the lateral expansion of the ingots during piercing, and therefore increase the force required for the piercing operation, as the dies cause the expansion to take place longitudinally. Besides this, the dies force the scale on the outside of the ingot into its surface, thus producing sears,

which are very objectionable, more especially when the ingots are to be subsequently drawn into thin tubes."

The ingot A, to be pierced, is supported on a table B, having an aperture C in it to receive the head of the

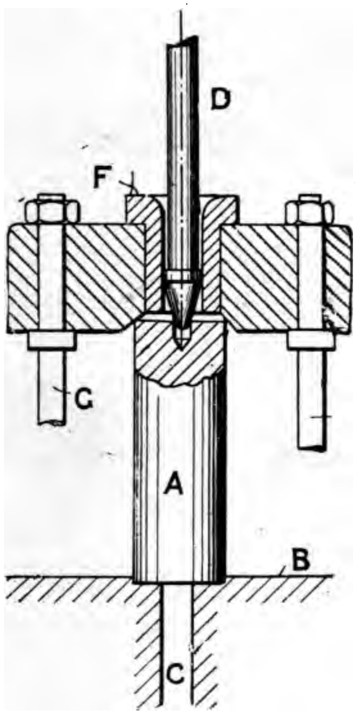
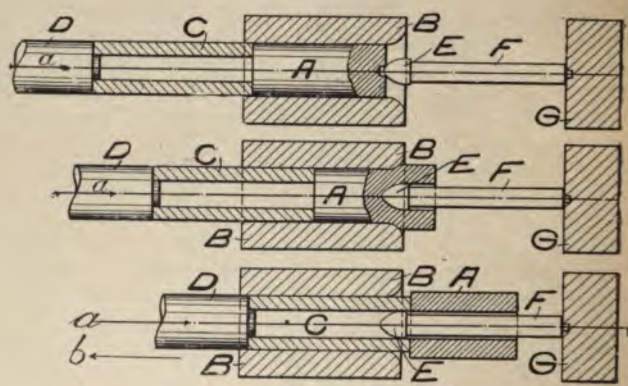


FIG. 105.

mandrel D on the completion of the piercing, The ingot or billet is held central by a recess in the underside of the crosshead E. A mandrel guiding bush F is placed in the head E as illustrated. The crosshead tie bolts, G are "so fixed to the table that they can be easily and rapidly raised

and lowered for the extraction of the pierced ingot, and the insertion of a fresh blank ingot." To "assist true centering of the piercing mandrel" a hole may be "drilled about one inch deep" in the upper end of the billet.

It would doubtless be extremely advantageous if lateral support for the billet could be dispensed with in such piercing operations; but with a steel billet in the white hot or glowing condition to which it must be heated, if the



FIGS. 106, 107, and 108.

piercing is to be accomplished with a reasonable expenditure of power, it appears necessary in practice to provide lateral support during the piercing.

In a later specification by the same inventor (E. L. Cooper), No. 15772, of 1899, the billet is supported by a die fixed in advance of the piercing mandrel, whilst the lateral displacement of the metal is arranged to occur in the bell mouth of the said die. Figs. 106, 107, and 108 are from the drawings accompanying the specification, on which no patent was granted. The ingot A is placed in the matrix or die B, into the one end of which is placed a hollow sleeve C, attached to a hydraulic ram D. At the other end of the matrix or die B is shown a mandrel E, on a stem rod F, at

the outer end of which is a crosshead G to support F during the time of piercing.

The method of operation is as follows :—

The ram D is raised, allowing room for ingot A and sleeve C to be put into the position as shown at fig. 106. Force is then applied on ram D by hydraulic power in the direction of arrow *a*, forcing C on to the back of ingot A, which is, in turn, forced forward and over mandrel E.

Fig. 106 shows the position ready for piercing; fig. 107 represents the ingot partially pierced and expanded; and fig. 108 the completion of the piercing.

CHAPTER IX.

The Extension of Hollow Steel Blooms by Hot Rolling and Drawing.

WHILST comparatively small hollow blooms, not exceeding about 3 in. in external diameter, and such as are generally employed for the manufacture of cycle tubes, can be extended in length and correspondingly reduced in thickness by rolling, in a hot state, over plug mandrels with a train of ordinary or continuous rolls, it is found advantageous with blooms of larger size, or where the metal is to be much reduced in thickness, to employ the type known as gapped, back-action, pilger, or step-by-step rolls.

Gapped or back-action rolls have been known and employed for many years for various forging operations. The specification No. 3371 of 1891 (Max Mannesmann) describes and claims a process of forming or rolling tubes upon a mandrel by gapped rolls which are characterised as having "grooves in part concentric and in part eccentric or tapering." Originally the specification claimed much more than this, but it was limited to the characteristic indicated above by an amendment effected at the end of the year 1898. The method of operation of all back-action rolls is very tersely described in the original claim 1 of the aforesaid specification of Mannesmann, which reads as follows :—

"The process of forming or rolling tubes and other hollow bodies upon a mandrel, wherein the metal object, during its passage through the rolls, has a step-by-step forward, with intermediate retrograde, motion imparted to it in such manner that it is operated upon successively on a limited portion of its length, such point of operation being made to advance in a longitudinal direction along the object."

"By this means"—to quote from the body of the specification—"the tube is not worked upon consecutively along its entire length, but only bit by bit, so that the point of operation progresses, as it were, from one end of the tube to the other. Thus, whereas in the ordinary process of drawing a tube, this is each time moved entirely through a die, the size of the tube being reduced by passing it consecutively through several drawing dies of decreasing size, according to the present invention the tube receives its final shape by being passed a single time through the rolls, between which it remains the whole time, performing a series of comparatively short longitudinal movements. If the end of the tube where the working commences be designated as the front end, and the opposite end as the rear end, while the movement of the tube from the rear towards the front end be called the forward motion, and the reverse movement the backward motion, then the working of the tube takes place during the backward motion, or a portion thereof. In some cases it is necessary after each action of the rolls to effect a partial rotation of the tube round its longitudinal axis, in order that the rolls may operate upon a different part of the tube." "The rolls serving to carry out this operation may either receive a continuous rotary motion in the same direction or they may have a to-and-fro reciprocating motion. The rolls have in part concentric and in part eccentric or tapering grooves."

Figs. 109, 110, and 111 are from the drawings accompanying the specification, the description relating thereto being as follows:—

"The rolls attack the tube during the backward motion. Fig. 109 shows by way of example the termination of such an attack where the concentric part of the calibre is already in action. The rolls A and B revolve in the direction of the

arrows 1 and 2. When the gaps *a* of the rolls face ea
other, as at fig. 110, the tube, together with the mandrel, ca
be again freely moved forward in the direction of the arrow
so that a further portion of the tube is presented to t
renewed attack of the rolls. The forward motion will
greater than the backward motion, so that the step-by-st
forward and intermediate retrograde motion shown in fig. 1
will take place. When the rolls attack the tube during t
backward motion, as at fig. 111, the rolling operation will ta
place from the thicker end of the tube towards the thinn
end, as will be readily seen. The calibre of the rolls will
course depend upon the desired section of the tube to
obtained."

The specification No. 6283 of 1894, of B. Price, describ
an "apparatus for making tubes from hollow ingots," on t
step-by-step method, "in which the operating swages

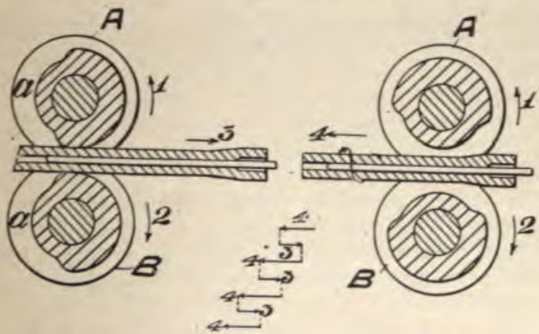


FIG. 109. FIG. 111. FIG. 110.

rolls are given a reciprocating movement in the direction
the length of the ingot, and at the same time are caused
approach one another on each side of the ingot." A lat
specification (No. 13985 of 1900), in the names of La
bourne, Marsh, and Price), describes certain improvemen
relating to the aforesaid apparatus, comprising means f
feeding the work between the rolls or swages, and for t
removal of the elongated tube from the mandrel.

In the specification No. 14416 of 1900 (O. Heer, of Düsseldorf), the housings of gapped rolls are swung on a horizontal axis, "thus reducing shock when work is inserted."

In ordinary machines employed for feeding the work through gapped or back-action rolls, the feeding action cannot be continued until the complete length has been operated upon, for fear of seizure by the rolls of the forward end of the push bar of the feeding machine. It has been a usual practice, to avoid such an accident, not to attempt to feed the hollow bloom right through the rolls, but to leave a waste or unrolled piece on the rear end of it. In addition to waste of metal, this involves a subsequent operation for the cutting off or removal of the said thick end. To overcome the difficulty the use of a hot waste

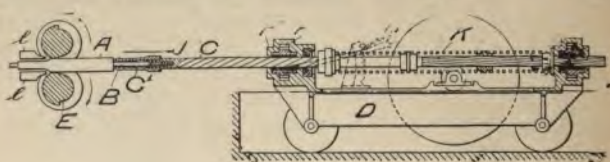


Fig. 112.

block between the rear end of the bloom and the nose of the push bar has been suggested, but this necessitates the use of a freshly-heated block with each bloom, so that it shall be soft enough to yield readily when the working parts of the rolls press upon it.

A more satisfactory solution of the difficulty is shown at fig. 112, illustrating the feeding machine described in the specification No. 12203 of 1900 (A. E. Beck). This machine appears to be provided with a conically nosed socket piece at the forward end of the push bar, such as is described in the specification No. 5425 of 1900 (H. Perrins). Referring to fig. 112, A represents the hollow bloom or piece of work, B the mandrel detachably screwed into the forward end of the push bar C, beyond which projects the conically nosed socket C', D the wheeled carriage (advanced by rack and pinion device) supporting the push bar, and E E' the

gap rolls with work stops *e* at the rear side. The following extract from the specification describes the manner of feeding the rear end of the work through the rolls :—

"When the bloom or tube use A has been nearly passed through the rolls E E′, it is ordinarily necessary to disengage the mandrel B from the push bar C, and then either to complete the feeding through the rolls by hand or leave an unworked piece of metal at the end of the bloom, which has subsequently to be removed. But by my present invention the mandrel B, when the tube has been nearly passed right through the rolls, has an advancing and releasing motion imparted to it relatively to the push bar in which it is supported, or the bar is caused to retreat from the mandrel, to enable the rolls to bite and operate upon the metal right up to the rear extremity of the bloom, and thus to permit of the automatic feeding of the said bloom and its freed mandrel completely through the rolls. In one method of effecting the automatic relative movement between the push bar C and the mandrel B, I form a quick screw thread or threads around the fore part of C (the direction of spiral being opposite to that of the slow pitch screw thread at the rear end of the bar), and pass the same through a nut F having ratchet teeth formed around its perimeter. Normally the said nut is free to rotate in either direction within the box F′ as the screwed push bar passes through it, but after the hollow bloom or tube shell A has been nearly passed right through the rolls, the nut F is locked or prevented from rotation by a pawl lever which is then thrown into engagement with the ratchet teeth of the nut by means of any suitable lever device, as H. When the nut is thus locked, or prevented from rotation in the one direction, the push bar C on each return stroke (or movement in the direction indicated by the arrow J) will have such a rotary movement imparted to it, whilst the tube and its mandrel are gripped tightly between the rolls, as to cause it to unscrew and retreat from the mandrel B. In this manner the socket-like projection C′ (which is in rigid attachment with the bar C), or other nose of the bar, is carried back at each stroke a sufficient distance to clear the rolls and enable the same to bite and operate upon the rear end of the metal

forming the tube bloom, and thus the entire bloom is automatically passed—by the continuous action of the feeding machine—right through the rolls as a finished tube."

The slow pitch screw thread at the rear end of the bar, referred to above, is for the automatic rotation of the work during its return to the rolls under the action of the spring K, to bring the entire circumferential surface of the tube under the action of the rolls.

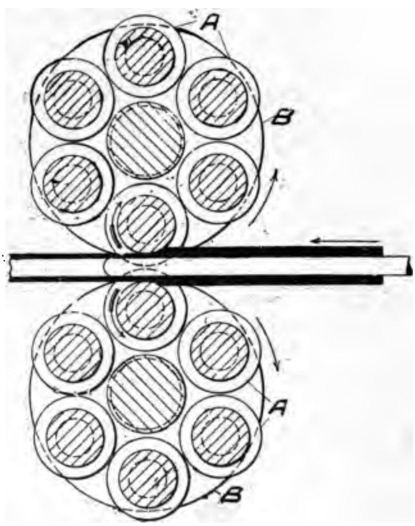


FIG. 113.

The tube rolling machine, as illustrated at fig. 113, is from H. Ehrhardt's specification No. 12747 of 1899. Freely rotatable rollers, as A, are mounted on the discs B rotated, as indicated by the arrows, in a contrary direction to the movement of the work which is fed or drawn through the machine. " The rollers roll and press on the work, the latter being thereby drawn out and forced to assume the

required profile or shape. It is, however, immaterial in which direction the work moves; it may advance in or against the movement of the rollers; the rollers may also differ from each other as regards dimensions or diameters of their projecting or recessed parts, forming increasing or decreasing profiles for the purpose of effecting a more energetic rolling or shaping of the work." The device is described as permitting "a periodical rolling or drawing out while the work steadily advances."

Shortly after the above-named specification of Ehrhardt, there was filed on behalf of R. H. Keithley, of New York, the specification No. 17473 of 1899 (from which fig. 114 is

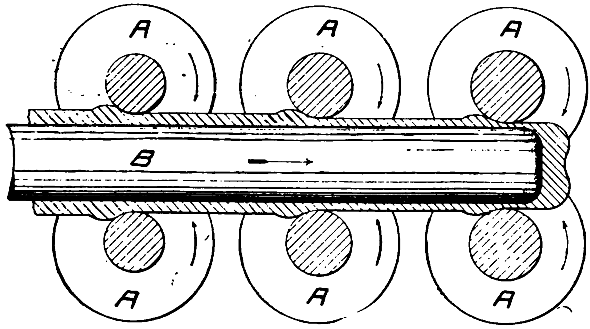


FIG. 114.

taken), describing another arrangement in which rolls are caused to rotate in opposition to the advancing movement of the tube. The invention is described as having for its object the provision of "an improved method and apparatus for the economic manufacture of seamless tubing of superior density and toughness."

The following is from the body of the specification:—
"In the manufacture of seamless tubing prior to the present invention, two operations have heretofore been found absolutely essential. The first operation or process is what is known as the hot process. At the present time, the hot process of rolling tubing is carried out by a variety of

machines. In the first class of machines for performing the hot process, a heated billet or blank is mounted or secured upon a mandrel, and is reduced in diameter by ordinary straight-line rolling machines of a similar construction to those employed for rolling rods. In other cases power has been applied to force the mandrel and blank through rolls which are idle or free to turn. In recent years, the apparatus employed in the hot process of tube rolling has been modified or improved in a variety of ways, as, for example, by the substitution of inclined discs for the straight-line rolling mills previously employed. These discs have been set at an angle with respect to the path of the mandrel so as to produce a spiral action, as it were, upon the billet or blank, and various other changes have been made upon specific sets of apparatus employed—that is to say, the advances or improvements in the manufacture of seamless tubing have in recent years been designed with a view of discarding the old type of direct, straight-line rolling mills, and have been produced with a view of perfecting the more complicated types of the variously modified disc rolling machines. With none of the prior methods of hot rolling, either practised with the ordinary straight-line rolling mills or with the later disc rolling mills, has it been possible, however, to produce a finished tubing by the hot process alone. All these prior hot-rolling processes affect only the outer layers or surface of the tubing being produced, and the inner layers of the hot rolled tubes have not heretofore been compacted to the same degree as the outer layers or surface thereof, and in order to produce a finished tubing, it has heretofore been absolutely essential to use an additional or second finishing process. This second finishing is commonly known as the cold process, and it ordinarily consists in drawing the unfinished tubing made by a hot process through a stationary die or dies. This second finishing or cold process will compact and harden the outer layers of the tubing, and will produce tubing substantially uniform in diameter; but even after the application of the second finishing or cold process, the inner layers of tubing thus produced will be left comparatively soft or of comparatively light density.

The present invention has been designed with a special view of producing finished tubing by a single hot process, thereby eliminating from the manufacture of tubing of this class one set of apparatus, and the entire second finishing or cold process which is now necessarily employed. To accomplish this result, this inventon has returned to the old form of straight-line rolling mill, and the desired result is accomplished by using the rolls of this old apparatus, so that, instead of allowing said rolls to act in the ordinary manner, they are turned in opposition to the advancing movement of the ingot. This will cause the rolls to act upon the metal of the blank with a novel heavy roll-drawing action, which

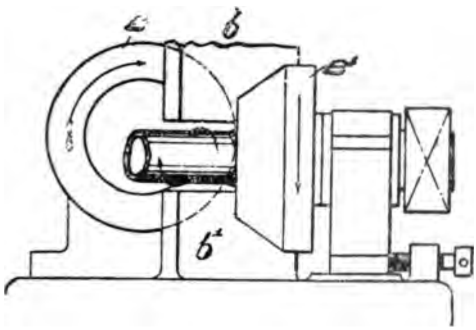


FIG. 115.

will produce a stretching, straightening, and compacting of the fibres under pressure; that is to say, the metal will be supported on the mandrel as upon an anvil, and will be caused to flow thereon, as it were, so that the entire mass or body of metal will be uniformly compacted and made homogenous throughout its thickness, and, by this improvement in the art, this invention may produce by a single process finished tubing which it has heretofore been impossible to produce without the addition of the second finishing or cold process."

The rolls A are positively rotated in the directions indicated by the arrows thereon, which is in opposition to

the advancing movement of the mandrel B, "which may be reciprocated and simultaneously revolved, if desired, by any ordinary means," such as a hydraulic cylinder.

Fig. 115 is an elevation and fig. 116 a sectional plan representing a type of machine for stretching or elongating hollow steel blooms, described and illustrated in the specification No. 3788 of 1900, of G. Beesly. The hollow billet A is operated upon at the pass formed between the adjacent sides

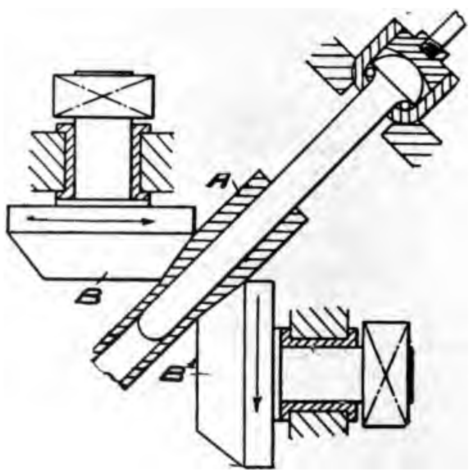


FIG. 116.

of the discs B B′ arranged at right angles to each other. "Both discs are positively driven, and the centre of the one is arranged above the centre of the other, as illustrated. The action of such discs is, therefore, to set up a rotation of the billet A, and at the same time to give it a progressive or forward motion. The directions of the various movements are indicated by the arrows." The mandrel is held in tension in the pass, as illustrated, whilst the bloom is guided or kept in its proper path by guides *b b′*.

Taper Tubular Steel Poles.

Tubular poles, such as are employed for the support of the overhead conductors or wires for electric tramways, can be made without great difficulty in a tapered form if welded tube of wrought iron or mild steel is employed. But seamless steel tube manufacturers generally prefer to make such poles from two or more lengths of differing diameters socketed together, finding this to be more convenient than to produce one long and continuously tapering length.

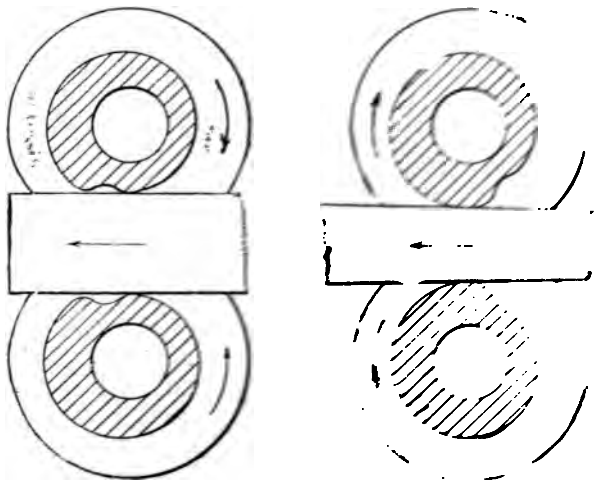


Fig. 117.

Figs. 117 and 118 illustrate the mea[illegible] specification No. 2666 of 1[illegible] [illegible] "drawing and rolling tubes to a [illegible] or to a varying transverse section at [illegible] length." "For this purpose, the [illegible] employ as a die a pair of rollers [illegible] revolve at equal surface speed [illegible] having a circumferential groove [illegible] transverse section of the tube, that section [illegible] at different

parts of the circumference, it may be, in the same order and proportions as the desired variations of the tube. While the rollers revolve the tube to be operated on, preferably heated, is drawn through between them at any desired speed, the variations of section being thus made over lengths of the tube proportional to the speed at which it is made to travel relatively to the surface speed of the rollers. If the rollers remain at rest while the tube is drawn, the section of the tube will be uniform."

Figs. 117 and 118 are transverse sections of the pair of rollers which constitute the varying die, showing diagrammatically the positions of the rollers relatively to a taper-drawn tube at the beginning and the end of the draw respectively.

CHAPTER X.

Cold Drawing.

The reduction of the thickness and corresponding extension in length of seamless tubing, by drawing such tubing in a cold state through fixed dies, has been continuously carried on in the Birmingham brass and other metal tube trades for nearly eighty years. The same process is employed in the final reduction of steel tubes for use in the construction of cycle frames and for other purposes. Seamless steel tubes for use in water tube or tubulous boilers are also subjected to a cold drawing. The well-known "draw bench" of the endless chain type is the machine most generally employed for cold drawing, though for heavy work or tubes of large diameter hydraulic machines are adopted.

Fig. 119 is from the specification entitled "Improvements in Draw Benches" (15419 of 1899) of G. A. Muntz and A. J. Astbury. The stated object of the invention "is to automatically effect the return motion or traverse of the draw-bench dog-wagon or carriage after it has made its advance motion or traverse, and after the tube or article has been released from the die and the wagon from the drawing

power." Such return of the dog-wagon is usually effected by "an attendant," who, in most cases, is a small boy whose activity in the accomplishment of his task makes it appear that the motive power proceeds from the wagon itself, for the boy generally manages, by a dexterous initial kick off, to make the wagon carry him back along with itself to the die end of the bench.

The invention referred to, and illustrated at fig. 119, is briefly described in the following extract from the specification: "At the rear, and below the level of the bed of

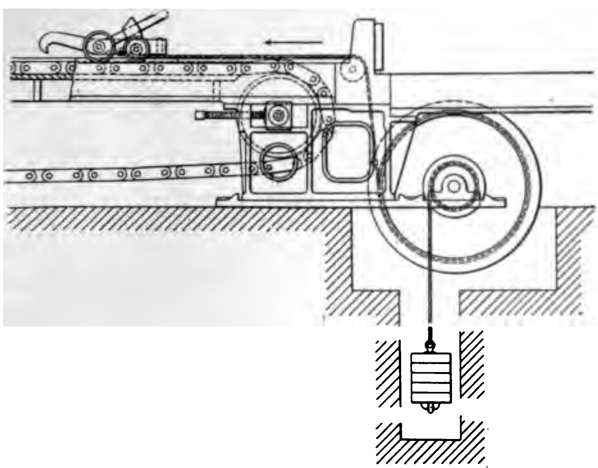


FIG. 119.

draw bench, we arrange a cross shaft carrying a pulley and working freely in its bearings. To the rear end of the dog-wagon or carriage one end of a rope or chain is attached, the other end of the said rope or chain being attached to the pulley described on the cross shaft, a guide pulley guiding the said rope or chain to and from the said pulley. As the dog-wagon or carriage makes its forward traversing motion on the bed of the draw bench, the rope or chain described is unwound from the pulley. As the dog-wagon or carriage makes its back or return motion, the rope or chain is auto-

matically wound upon the pulley in the following manner: On one end of the cross shaft carrying the pulley a small drum is affixed, on which a weighted cord or chain is coiled or uncoiled. As the dog-wagon or carriage makes its forward traverse, the said weighted rope or chain is coiled upon the drum and the weight is raised, the dog-wagon rope or chain being at the same time unwound from its pulley. On the release of the dog-wagon from the drawing power the weight descends, and the weighted rope or chain is unwound from its drum, giving rotation to its shaft and to the pulley

FIG. 120.

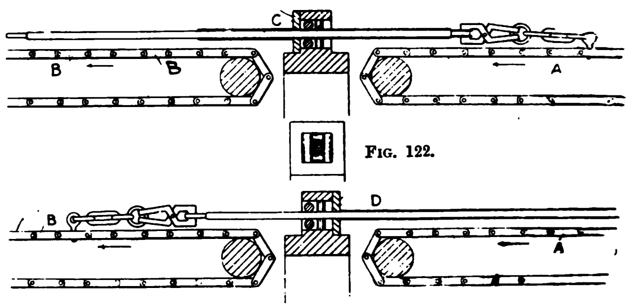


FIG. 122.

FIG. 121.

upon it, and effecting the winding of the dog-wagon rope or chain upon the said pulley, and thus automatically giving the return or back traverse to the dog-wagon or carriage."

In cold drawing, the tube naturally becomes very tightly closed upon the bar or mandrel as it passes with it through the reducing die. The subsequent release of the combined parts is generally effected by "reeling" or rolling, whereby the tube is sufficiently loosened to permit of the ready withdrawal of the mandrel; such withdrawal is frequently accomplished by connecting the mandrel to a draw-bench chain whilst the tube is held back by a stripper or thrust plate, ring, or fork piece.

Figs. 120, 121, and 122 are from the specification No. 28699 of 1897, of Ellwood Ivins, of Philadelphia, Pa., U.S.A.,

whereby the "reeling" or loosening of the tube upon the mandrel is effected simultaneously with the drawing. The patentee states that he combines "with the draw head of the machine means for so acting upon the tube immediately after it issues from the draw plate, that by the time the drawing operation is completed the drawn tube will be expanded throughout its entire length, and the core or mandrel can be removed therefrom. Fig. 120 is a diagrammatic view of sufficient of a draw bench to explain the invention, the drawing of the tube being illustrated in progress. Fig. 121 is a similar view showing the tube being removed from the mandrel." Fig. 122 is an end view showing the arrangement of the rollers for "reeling" or loosening the tube. The patentee describes his preferred means for effecting the "expansion of the tube" as "a series of rollers so disposed that they will bear upon the tube at four points, which, viewed transversely, are equidistant (see fig. 122), and will compress the said tube at those points sufficiently to cause it to bulge or spread between the points of contact, whereby the hold of the tube upon the core or mandrel is so reduced that the said core or mandrel can, after the passage of the tube through the rollers, be readily withdrawn by power suitably applied to the end of the mandrel opposite that to which power was applied in drawing the tube. In order to effect the ready withdrawal of the mandrel I use a supplementary draft chain B in front of the draw head, and travelling in a direction the reverse of that of the chain A. When the tube and its mandrel have been drawn through the die plate C and rollers, a stripper plate D is applied to the draw head, as shown in fig. 122, and the rear end of the core is passed through the opening in the said plate, and connected by any suitable means to the rearwardly travelling draft chain B, the stripper plate being such as to act as a stop for the tube, so that the mandrel will be withdrawn from the same, and, when so withdrawn, will occupy a position in front of the draw head, where a new tube can be applied to it. By this means any handling of the drawn tube, with its enclosed mandrel, is rendered unnecessary, since there is no need to carry the tube from the rear of the draw head to the front thereof, or to turn the tube and its

enclosed mandrel end for end in order to permit of the withdrawal of the mandrel, and therefore the whole operation can be very cheaply and expeditiously performed."

To facilitate the cold drawing of weldless steel tubes the specification No. 10539 of 1897 (A. C. Wright) describes the use of a coating of tin as a lubricant. The following description is from the specification:—

"In the ordinary process of drawing tubes or tube blanks the surface of the tube and that of the dies or other tools are freely lubricated with oil or grease or like unctuous substances, and such drawing down process necessitates a great expenditure of mechanical energy. After the tube has been drawn or reduced to the required dimensions, it is necessary to thoroughly remove the whole of the grease in the event of the tube surfaces requiring to be plated or japanned, as otherwise such operations cannot be efficiently performed."

"In drawing tubes or tube blanks in accordance with my invention, I prevent the actual contact of the surfaces of the steel or other tube to be drawn with the surfaces of the dies or other tools, by an interposing film of soft metal or anti-friction metal; such metal by gliding through the die along with the tube acts as an efficient lubricant exactly in the place required, and is not pushed off the tube at the die mouth as with ordinary lubricants. The metal which I preferably employ consists of a mixture of tin and lead, in the proportion of six parts tin to four parts lead. Such a mixture, in addition to being cheaper than pure tin, gives a better coating upon the tube. The anti-friction metal can be applied either by immersion of the tube or tube blank in a bath of the molten metal before submitting it to the drawing process, or in other convenient manner. By thus employing an interposing film of anti-friction metal between the surfaces of the tube or blank and the dies or mandrels, or operating tools or appliances, I am enabled to dispense entirely with the use of oil, grease, or like unctuous substances, to effect a great saving in the wear of the dies and mandrels, and to very materially reduce the expenditure of mechanical energy and the time required for the drawing or reducing process. My treatment also permits of the employ-

ment of a cheaper steel for the production of weldless steel tubes for cycles and other constructional purposes, the tube produced therefrom being quite equal in quality to the tubes produced in the ordinary manner from Swedish steel. I am also enabled to draw tubes of hard white metal and other alloys, such as cannot be otherwise drawn, and to facilitate the drawing of copper, brass, and the like tubes."

"In the drawing of weldless steel tubes I do not remove the tube from its mandrel until it has been finished to the required size, passing it several times through dies without annealing and pickling between the passes, but, after each pass or after the tube has been drawn through each die, I subject it to the action of a reeling or releasing machine, to sufficiently release the tube to permit of the free flow of the metal in the next draw or pass. Thus in the drawing of a tube whose thickness on leaving the rolls is equal to about No. 11 gauge down to a thickness equal to No. 20 gauge, I first coat the tube with anti-friction metal (after annealing, if necessary), and then draw it through a series of five or six dies until reduced to the required finished size. After leaving each die the tube is reeled, but not taken off the mandrel, before being passed through the next."

The drawing of a number of tubes simultaneously on the one mandrel is described in the specification No. 3372 of the year 1902, filed on behalf of La Société Vogt and Cie, of Niederbruck, near Maxmünster, Alsace, Germany. A number of tubes are nested together and drawn on the one mandrel inserted in the innermost tube To prevent what is termed "a grinding or welding together" of the nested tubes, they are covered with "a thin protective coating (for example, of milk of lime or of a mixture of graphite and coal)."

Combined Drawing and Rolling.

Fig. 123 is from the specification No. 4629 of 1902 of Max Mannesmann, showing the combination of a draw-bench device with rolls. A sufficient description is given by the first claim, which reads as follows: "The improvement in the rolling of tubes, which consists in rolling a hollow billet or blank between positively-driven rolls and a positively-

driven endwise-actuated mandrel, the velocity of the mandrel being greater than the peripheral velocity with which the calibre of the rolls revolve, whereby the stretching out of the hollow blank is facilitated or the crowding up of the rolled out part of the tube in longitudinal direction is prevented, substantially as described." It will be observed

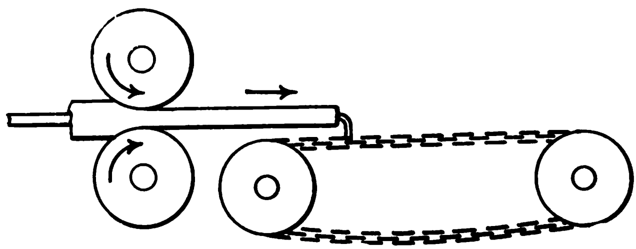


FIG. 123.

that, unlike the Ehrhardt and the Keithley machines described in a former article, the movement of the rolls is in the same direction as that of the independently actuated mandrel. The following patent specifications of Max Mannesmann are concurrent with the foregoing: 4553, 4554, 4625, 4626, 4627, 4628, all of the year 1902.

DRAWING WELDLESS TUBES WITH BUTT ENDS OR THICKENED ENDS.

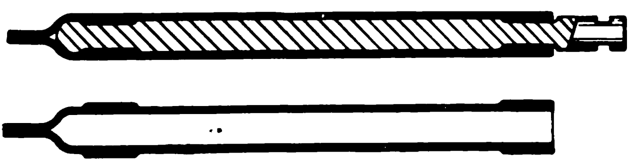
Figs. 124 and 125 are from the specification No. 24931 of 1897, of A. M. Reynolds and J. T. Hewitt, of Birmingham, describing the drawing of tubes with a varying distribution of metal. The particular figures selected illustrate the manufacture of a double butted tube, or a tube with both ends thickened. The mandrel is necked or reduced at the required positions to give the thickened portions of tube. On subsequently withdrawing the mandrel the said thickened portions are expanded, thus providing a uniform internal bore, as at fig. 125. If the tube is required in this form the closed or tagged end is then cut off. But if, as in the case

ycle tubing, a uniform external diameter is required, the e is drawn through a die, without a mandrel, for the pur-se of contracting the external projections: the thickened rtions are thus returned to the original or fig. 124 position.

A machine specially adapted for the drawing of butted or einforced tubes as aforesaid is described in A. M. Reynolds' pecification No. 4443 of 1899.

ANNEALING AND PICKLING.

By the ordinary methods of annealing, in which the tubes are exposed to oxidising gases during heating and to the air during cooling, there is a wastage of metal by the formation of oxide on the tube surfaces. For the complete removal of such oxide it is necessary to subject the tubing to the "pickling" process, which may set up a further wastage. A



FIGS. 124 and 125.

weak acid solution, consisting of one part hydrochloric acid to 39 parts water, is the "pickling" solution specified by the British Admiralty for the thorough cleansing of boiler tubes for examination prior to their acceptance from the manufacturer.

In several industries—notably in the manufacture of the bright steel wire used for making cards for the purpose of combing wool or other fibres, and also in the rolling of bright metal sheets or strips for various purposes—what is known as "bright annealing" is employed. By this process the articles are surrounded by an inert or non-oxidising atmosphere during the annealing process. According to one method of applying the process the articles are placed in an annealing box which is connected by a flexible pipe with an ordinary illuminating gas supply. The admission of the

coal gas drives out the air and maintains an inert or non-oxidising atmosphere within the annealing box throughout the annealing operation. The articles are thus not only protected from scaling but their original brightness is not lost nor impaired during annealing.

Close annealing and "bright annealing" appear to offer very considerable advantages to weldless steel tube manufacturers, and we understand that it has been adopted by some of them.

In his specification No. 4085 of 1902, for "Improvements relating to the treatment of metals during manufacfacture into various articles," Mr. T. Vaughan Hughes, A.R.S.M., of Birmingham, describes, *inter alia*, "annealing in the presence of a gas capable of acting chemically so as to remove any scale formed during previous processes of manufacture, thus virtually carrying out the annealing and pickling processes simultaneously." For this purpose he admits to the annealing furnace "a gas which will act chemically to remove any scale previously formed, and prevent the formation of further scale, such, for instance, as chlorine or hydrochloric acid gas in the case of iron and ammonia in the case of copper."

In his paper read in November, 1899, before the Cycle Engineers' Institute, on "Some Aspects of Steel Tube Making," from which an extract was given in an earlier article, Mr. Alex. E. Tucker, F.I.C., of Birmingham, makes the following reference to pickling:—

"The loss of expensively produced metal is again large in the pickling process, and the lessening of the leakage in monetary value is much to be desired. A process has lately been suggested for pickling sheets, in which the scale is removed electrically by making the sheets the anode in a practically neutral solution, and using a lead or iron plate as a cathode. The method would seem to be applicable to tubes. Special arrangements would have to be provided for their lengths and circular section. Perhaps, however, these might be met by threading the tubes on vertical iron legs, bolted to a strong wooden frame. The whole would then be lowered into the pickling vat filled with the neutral solution, and electrically connected with a small dynamo.

From experiments I have made in connection with this matter I find that a current of 3·8 amperes per square foot of surface, working in a neutral solution, very easily scales steel. If it should be found practically possible to use this method of pickling for tubes, there would be on the credit side a more uniform removal of metal than is possible when bundles of tubes are placed in a horizontal tank of acid water. Difficulties as to the disposal of waste pickle would be at an end, and as a minor advantage the iron taken off the tubes could be returned to the puddling or blast furnace for regeneration into more tubes."

Fig. 126 represents a pickling apparatus "for removing rust, cinder, or other foreign substance" from the surface of "metallic tubes, rods, and the like, which are to be subjected to cold-drawing operations," as described and illustrated in the specification No. 4897 of 1898, filed on behalf of Wm. A. McCool, of Beaver Falls, Pa., U.S.A. :—

"A is a tank containing the chemical reagent, such as dilute sulphuric or other acid. It is preferably of sufficient height to receive the entire length of long tubes or bars B supported by the carrier. The tube carrier comprises a central rod C, a perforated floor D, and one or more adjustable perforated plates E fixed at various distances from the bottom. In the bottom of the tank A there is a step F with a recess *f* to receive the end of the central rod C. At the upper end of the rod C is a swivel at G, and chain H by which the tube carrier can be raised and lowered. Below the step F is a valve I, which can be opened by means of a lever J when desired. K is a perforated pipe surrounding the step F and connected with a pipe K^1. The effect of admitting steam is to heat the liquid and cause it to circulate as indicated by the arrows. This circulation serves to carry the 'scale' or foreign materials removed from the metal surfaces by action of the acid to the inclined bottom of the tank, from which it can be removed by opening the valve I from time to time. The bottom *a* of the tank is inclined towards the valve, so that when it is open the escaping fluid carries with it all the deposited sediment."

"The tubes or rods, after being pickled, instead of being oiled as is usually done, are, according to this invention,

coated with paraffin wax or like material by immersi
in a tank in which it is kept in a melted conditio
heat of a steam coil or jacket. By using paraffin

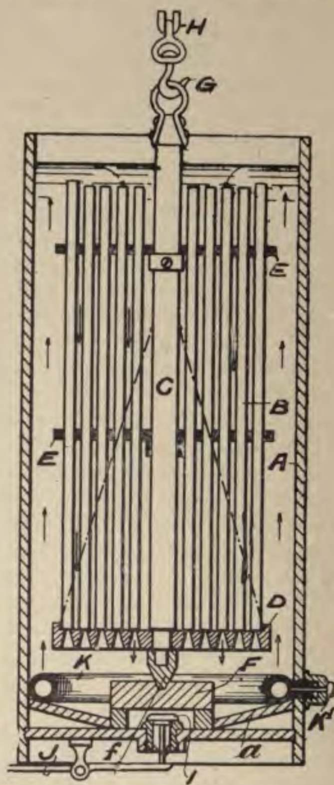


FIG. 126.

like material which sets solid on the pipe or rod, i
employing oil which is easily rubbed off, the coated
can be kept in store before being subjected to draw
retaining the lubricant, and when they are dr

lubricant scales off and can be collected for future use, whereas oil, when employed for lubricating the articles, becomes lost and covers the tools and workshop with masses of waste oil."

Steel for Weldless Tube Manufacture.

In his paper on the manufacture of weldless steel tubes by the Mannesmann process, read in April, 1902, before the South Wales Institute of Engineers, Mr. J. H. H. Barrée, in referring to the selection of the material, said: "The steel must be ductile, and must also possess considerable tensile strength, varying with the class of tube to be made. Homogeneity is very essential, and it must also be free from the following defects, to which mild steel is liable: blowholes, which afterwards become blisters; rooks, which develop into external laps and laminations; and scabs, which cause unequal thickness when the tube is rolled out. Another reason which renders the selection of the steel of great importance is the multitude of specifications with which the tube manufacturer has to deal, almost every engineer having his own pet theories on the subject, and each Government department having its own special requirements. It is, therefore, absolutely necessary that the tube maker should possess to a certain extent the knowledge of the steel manufacturer. Fortunately the British steel manufacturer is now beginning to realise that the steel tube trade is a large and important consumer and is able to supply suitable material for ordinary work, but for the highest class tubing in cold-drawn finish the tube manufacturer has mainly to rely upon the Swedish steel makers."

In connection with the foregoing it may here be observed that a few years ago the Admiralty, with a little regard perhaps to the encouragement of home industries but a greater consideration for convenience of inspection and testing during manufacture, attempted to compel the employment of nothing but British steel in the manufacture of weldless boiler tubes. It was found, however, not from any want of skill on the part of the British steel makers but because of the natural qualities of the raw materials, both ore and fuel,

available in Sweden, that to insist on such a condition was not in the best interests of the Service and occasioned much trouble and loss to our steel-tube manufacturers. It was accordingly withdrawn.

Some tensile tests which we made on three test pieces prepared from as many billets of Swedish steel for use in the manufacture of cycle tubes gave the following results:—

	Ultimate load.	Elongation in 8 in.	Reduction of area.
A	32·29 tons per sq. inch.	19·5 per cent.	57·3 per cent.
B	37·93 ,,	20·0 ,,	42·1 ,,
C	32·49 ,,	26·5 ,,	55·5 ,,

A chemical analysis on borings taken from these samples gave the following:—

	A.	B.	C.
Carbon	0·283 per cent.	0·353 per cent.	0·213 per cent.
Silicon	0·034 ,,	0·052 ,,	0·047 ,,
Sulphur	0·017 ,,	0·017 ,,	0·021 ,,
Phosphorus	0·002 ,,	0·002 ,,	0·002 ,,
Manganese	0·262 ,,	0·297 ,,	0·316 ,,

It will be observed that the sample B (containing a comparatively high percentage of carbon) has a tensile strength considerably in excess of the samples A and C. In the manufacture of tubes from the steel represented by these samples great trouble was experienced in the cold drawing and much waste through defective places in the steel and the consequent splitting of the tubes at such places during reduction to the required gauge. The conclusion arrived at was that steel such as that represented by the sample B was unsuitable for the production of thin gauge tubing as required for cycles.

It is important to remember, however, that very low carbon and soft steels such as may be quite suitable in tubes for other services, may be useless for cycle tubes, as in addition to being insufficiently rigid to resist the stresses imposed upon them in a cycle frame, the hot spelter, during the brazing of the frame joints, may burn through the thin metal.

Some steels employed for the construction of cycle tubing, and that of excellent quality, vary very considerably in

composition from the samples above named. In particular the percentage of silicon and phosphorus may be much higher, the former element being sometimes present to the extent of slightly more than 0·5 per cent. The carbon may also amount to ½ per cent and the manganese exceed the percentage named in the above tests.

The tests recorded hereunder were made by the author on two annealed strips, cut from cycle tubing of No. 21 gauge (B.W.G.), which represents a thickness of 0·034 in. :—

Ultimate tensile load.	Elongation in 8 in.
26·67 tons per square inch	12·5 per cent.
28·24 " " "	10·0 "

A chemical analysis gave the carbon as 0·290 per cent.

For boiler tubes a very mild steel is generally employed. The British Admiralty very wisely leave to the makers the chemical composition of the metal for cold-drawn boiler tubes, but call for a tensile strength in the annealed billet of 21 to 24 tons per square inch, with an elongation of 33 per cent in 2 in. Strips cut from the tube, which may be annealed before testing, are required to show a tensile strength not exceeding 26 tons per square inch, with 27 per cent extension in 2 in.

Steel having a carbon percentage as low as ·01 to ·015 per cent has been employed for cold-drawn seamless tubes. It has been suggested that a mild steel with but such an exceedingly low percentage of carbon (less than is usually present in wrought iron) might more appropriately be termed "ingot iron."

CHAPTER XI.

Welded Tubes.

Wrought iron tubes for the conveyance of gas, water, and steam are still chiefly made according to the methods introduced in the first half of last century. Various improvements have been effected in the machinery and appliances

employed, but the processes followed are substantially the same as were evolved and established in and around Wednesbury by James Whitehouse, the Messrs. Russell, and others, between 1827 and 1850.

Whether butt-welded or lap-welded tubes are required, the manufacturer must first obtain his rolled "strip" from the ironmaster and convert the same into the "skelp" or open jointed tubular form.

Butt-welded tubes are listed by the makers as small as one-eighth of an inch internal diameter. Lap-welded tubes are internally supported by a plug or mandrel or its equivalent during welding, and cannot, therefore, be obtained of so small a diameter. The ordinary minimum internal diameter of lap-welded tubes is about one inch.

The following description of the manufacture of lap-welded iron tubes, as set forth in Thomas Henry Russell's specification, No. 10816 of the year 1845, may be of interest:—"The tubular skelp, drawn from a furnace at a welding heat, is placed upon a mandrel, or what the inventor terms a 'beak-iron,' which has a working surface of steel, and is rigidly fixed at one end in a horizontal position, its free end projecting over a draw-bench. The free end of this beak-iron affords the necessary resistance and support when the lap-joint of the tube, in order to weld it, is pressed upon by a roller, whilst the tube is drawn off the beak-iron by the action of the draw-chain, to which the grippers that have hold of the tube are attached. This system of working answers for tubes of large size, which are welded thereby at two operations, one-half at a time. In making small tubes the mandrel, or beak-iron, is required to be longer and of small diameter, and, consequently, as there is not sufficient substance to support the tube and its own weight horizontally without deflection, it is supported by a roller beneath the tube, whilst the welding roller above is operating upon the seam, the draw-chain dragging the tube forward. The skelp in this case is drawn direct from the furnace on to the beak-iron."

The steam tubes of leading makers are one gauge thicker than water tubes, and the latter one gauge thicker than gas tubes. The particulars given hereunder are from the pub-

	Gas.			Water.			Steam.		
Bore.	Standard wire gauge.	Thickness in inches.	Weight in pounds per f ot.	Standard wire gauge.	Thickness in inches.	Weight in pounds per foot.	Standard wire gauge.	Thickness in inches.	Weight in pounds per foot.
ins.		ins.	lbs.		ins.	lbs.		ins.	lbs.
¼	14	·080	·290	13	·092	·419	12	·104	·448
⅜	13	·092	·560	12	·104	·627	11	·116	·694
½	12	·104	·840	11	·116	·924	10	·128	1·008
¾	11	·116	1·176	10	·128	1·288	9	·144	1·400
1	10	·128	1·680	9	·144	1·848	8	·160	2·016
1¼	9	·144	2·464	8	·160	2·632	7	·176	2·800
1½	8	·160	3·136	7	·176	3·472	6	·192	3·808
1¾	8	·160	3·463	7	·176	3·804	6	·192	4·145
2	8	·160	3·791	7	·176	4·137	6	·192	4·483
2½	7	·176	5·334	6	·192	5·846	5	·212	6·350
3	7	·176	6·310	6	·192	6·936	5	·212	7·563
3½	7	·176	7·309	6	·192	8·020	5	·212	8·732
4	7	·176	8·047	6	·192	8·767	5	·212	9·488

lished lists of Messrs. John Spencer Limited, of Globe Tube Works, Wednesbury:—

The thickness of metal provided (and the list may be taken as typical of the sizes adopted by the leading makers), affords a far greater factor of safety than would appear necessary from a consideration merely of the bursting stress to be resisted. Let us, as an example, examine a one inch internal diameter gas pipe. The bursting force is given by multiplying the internal pressure per square inch by the internal diameter or bore in inches. Thus as a one inch pipe is of unit bore, the pressure per square inch will also be the bursting effort, and if the ultimate tensile strength of the iron be 20 tons per square inch (it should not be less), the pressure required to burst a pipe having a weld equal in strength to the strip itself will be—

$$20 \times (\cdot 128 \times 2) = 5\cdot 12 \text{ tons per square inch.}$$

The actual pressure of the gas conveyed by the pipes will in most cases not reach as many pounds. But the weld will by no means come up to the stated condition, and indeed, in some places, where through the interposition of a particle of scale, or for some other reason, a true weld is wanting, the tube may not even be gas tight. Further, the screwing of the tube ends will of course reduce the effective thickness of metal at such parts. All gas, water, and steam pipes, and fittings for same, must therefore be subjected to hydraulic test before passing from the works. Though for gas tubes a test pressure as low as 50 lb. per square inch is all that is sometimes specified by buyers, makers of repute prefer to adopt a much higher test pressure for all their tubes and fittings. Buyers' specifications for water and steam tubes seldom call for a hydraulic test pressure of less than 300 lb. per square inch, whilst as a test against "cold shortness," the tubes are required to stand bending cold through a right angle without fracture over a rounded block having a radius equal to but twice the bore of the tube.

Butt-welding is not ordinarily adopted for steam tubes of more than 2 in. internal diameter, and in some instances $1\frac{1}{4}$ in. is the maximum size made by butt-welding. Lap-welding is more effective and convenient for the larger sizes.

Lap-welded boiler tubes are made of several thicknesses in the same diameters to meet requirements. In fire-tube or tubular boilers (as distinguished from water-tube or tubulous boilers) the pressure acts upon the exterior of the tubes; they may, therefore, be safely made from thinner metal than is necessary for the resistance of an internally applied or bursting pressure.

Turning now to some recent patent specifications relating to the manufacture of lap-welded tubes, the illustration at

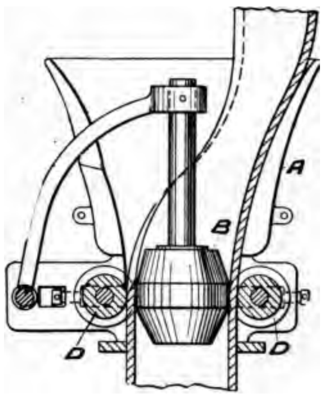


FIG. 127.

fig. 127 is from the specification No. 17986 of 1898, of C. Twer, of Eschweiter, Rhenish Prussia, shortly described as follows :—

" Wrought-iron gas pipes and the like are made with overlapping edges in an arrangement such as illustrated. The bell A, into which the skelp is guided, is provided with the mandrel B, supported from the pivoted arm C. The bell, which may be in two halves, carries rollers D, mounted in adjustable bearings. As the skelp is drawn forward its two overlapping edges are welded. The mandrel may be divided in order to render it elastic and to prevent a rupture of the bell. To reduce friction a small roller is sometimes placed in the interior of the mandrel at the place of contact between the mandrel and the tube to be welded."

Fig. 128 is from one of several illustrations appearing in the specification No. 22261 of 1898, setting forth an invention of E. E. Ries, of New York, the object of which is stated to be the production of "tubing in which the meeting edges are welded together in such a manner that the tubing may be re-drawn cold without weakening the joint, a process only possible heretofore with ingot or weldless formed tubing. A further object is to utilise the heating effect of an electric current or currents for producing an electrically welded or brazed seam during the process of forming tubes of this character, by which the heat is locally applied and

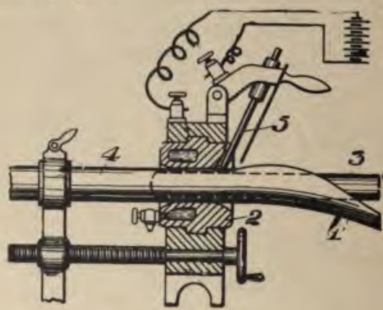


FIG. 128.

the heated metal protected to a very appreciable extent from oxidation and products of combustion, thus materially increasing the perfection and strength of the seam, and making this portion of the tube practically as strong or stronger than any other portion. I am also enabled by my improvements to manufacture tubes substantially equal in all respects, as regards strength and appearance, to seamless drawn tubing, while at the same time diminishing greatly the cost of production, both with respect to the number of operations required, the increased uniformity of the product, the saving effected in the original cost of the plant, and of greater economy in the use of heat."

Referring to the illustration at fig. 128, "the metal strip 1 is passed round a mandrel 3, and through a die 2, to form it into the tube 4. A cooling fluid is circulated

through a chamber in the die. The edges of the strip are brought to a welding temperature by passing an electric current through the carbon rod 5, the metal strip, the die, and back to the battery or other source. The die presses the heated edges of the strip so that they are welded together, and the tube is prevented from collapsing by the mandrel. A hand wheel and other gearing are provided to draw the strip through the die. The die may be fitted with rollers, and the mandrel may have a roller fitted in its head. The tube may be heated after passing through the die, which subjects it to a slight drawing process. The weld is completed by passing the tube through a 'welding clamp,' consisting of two hinged jaws which squeeze the tube."

The production of lap-welded tubes by a rolling-mill is described in the specification No. 16550 of 1899, of E. Johnson, of Wednesbury, the invention comprising a movable guide adapted for the guidance of the work into either the preliminary or the final welding groove or pass of the rolls. The process is described as follows :—"Skelps with lap-joints having been made, they are placed upon mandrels and heated in a heating furnace, of the ordinary kind, in front of the rolls. A heated skelp, or partly-made tube, is conveyed from the furnace into the trough guide in front of the first groove or hole in the rolls by which it is guided to the said groove; it is then seized by the said groove and its joint partly welded. The tube passed through the rolls is returned to the furnace and conveyed a second time to the guide and first groove in the rolls for further welding if necessary or desirable. The position of the movable tongue or guide check being reversed, a trough guide is formed in front of the second groove or hole in the rolls, and the partly welded tube having been re-heated is passed one or more times through the second groove or hole to finish or perfect the welding of the joint. In this way long tubes can be readily welded at one operation, that is, before the tubes are allowed to cool. The welded tubes are straightened in the ordinary way."

CHAPTER XII.

The Production of Tubes Direct from Piled Hollow Blooms.

Though the manufacture of tubes for the conveyance of gas, steam, and water, and for other purposes, by skelping and welding rolled iron strips on the systems of Whitehouse and others, has been followed for so many years, various inventors in this and other countries have felt that a more direct system is needed and have striven for such a system. To produce "tube strip" from the rough "puddled bars," or "muck bars" as they are termed in America, much rolling is necessary. But if during such rolling the hot crude metal which is thereby subjected to the necessary compressive working or forging to bring it to condition can be made into a tubular instead of a flat strip form, an enormous saving is apparent. The very statement of the problem may appear to give the solution. There are, however, various practical difficulties which may in part be appreciated when it is remembered that in "puddled bars" or "muck bars" we have the iron in an exceedingly crude condition and containing a considerable admixture of impurities. These impurities in the rolling of the bars become squeezed towards the edges, so that at such parts it is particularly difficult to effect welding.

Further, anything in the nature of wiring, banding, or other similar means for holding a pile of the bars together to form a hollow bloom or inchoate tube has been found altogether inadmissible. Such a method of securing the components of a "pile" or "faggot" may be employed when the subsequent initial welding, after removal from the furnace, is effected under a steam hammer; it is dangerous and unreliable when the pile has to be passed through rolls.

Fig. 129 illustrates the solution of the problem furnished by H. Perrins in his specification No. 22947, of 1897. The following description is extracted from the specification :—

"In making round section wrought-iron or steel tubes in

accordance with my invention, I first form what I call a piled hollow or tubular bloom as follows: In an ordinary rolling mill, with the rolls turned to the proper shapes, I roll puddled iron bars or other iron or mild steel bars to the trough sections shown in the figure, and so that the complete self-supporting pile may stand on one of the flat sides of the outer bars. Care must be taken that the edges of the bars are separated as illustrated. The piled hollow

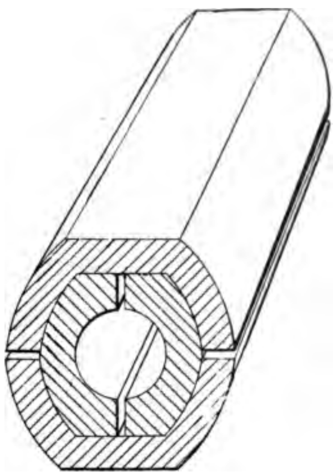


FIG. 129.

bloom, as aforesaid, is raised to a welding heat in a suitable furnace, being placed with one of its flat sides on the furnace bed. As there are two flat sides, forming the top and bottom respectively of the pile or piled bloom, the latter can be turned over in the furnace, and will stand steady on either of the said sides and thus be prevented from rolling in the furnace. When at a welding temperature, the pressure of the uppermost outer bar upon the inner bars and the pressure of the said inner bars upon the lower outer bar, cause the parts to become united or partially

welded along their adjoining circumferential surfaces, and by such welding before removal from the furnace the bars will be secured and retained in their proper relative positions during the subsequent rolling operation which completes the welding. The piled hollow bloom is rolled down at one heat thin enough to form some sizes of gas, water, steam, or other tubes."

The fundamental feature of the Perrins' process is, as is set out in the claim with which the specification concludes—the manufacture of wrought-iron and steel tube from hollow blooms formed by piles of inner and outer bars so shaped and arranged as to cause them to hold together and to unite in the furnace when raised to a welding temperature.

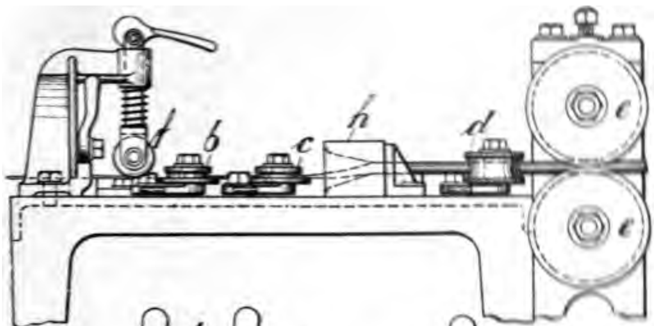
Cased Tubes.

Brass-cased tubes, as employed for bedsteads, fenders, and the like, and brass-cased stair rods are said to have been invented by Sir Edward Thomason in the year 1803, though from the British Patent Records they would appear to have been invented, or at any rate patented, a few years later and by another person.

In the manufacture of cased tubes, or composite or consolidated tubes as they are frequently termed in America, efforts are made to associate with the employment of the thinnest possible case a ready and convenient method of effectually concealing the joint. In what is known as "close joint" cased tube, the edges of the case are simply tucked under the edges of the tubular iron core or "inside"; the joint is then plainly visible. In "brazed cased tubes" the case edges are brazed together. This generally involves the employment of a thicker case and of metal of a rather better quality to enable it to withstand the brazing heat. With a good brazed cased tube, however, the joint is quite invisible after finishing and lacquering. In the manufacture of brazed cased tubes it was usual to reduce the case, or the metal to form the case, to the desired thickness (or thinness) before brazing. But under more recent practice thicker metal is brazed into a case, which is then drawn on a mandrel to the finished gauge before placing over and closing upon the iron core or inside.

The illustrations, figs. 130, 131, 132, and 133, are from the specification No. 566, of 1899, filed on behalf of A. P. Alvord, of New York, describing a method and means for the "making in one operation from two blank strips of metal a compound tube consisting of a slotted hollow core and a surrounding shell having flanges that project into

Fig. 130.



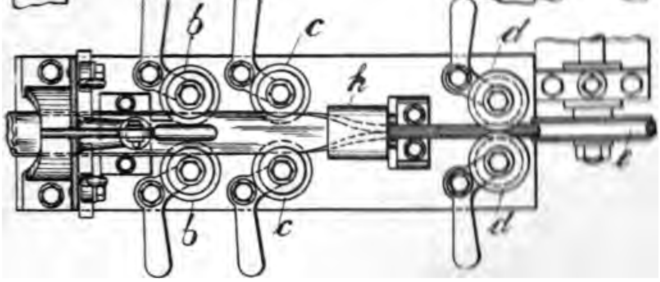


Fig. 131.

the slot of the core." In other words, it is a method and means for making both "inside" and "case" together, and simultaneously uniting or closing the one upon the other. On the bed of the machine three pairs of rolls are pivotally mounted, namely, the flanging rolls *b b*, the upsetting rolls *c c*, and the shaping rolls *d d*, between which the blank is drawn by the positively driven or power rolls *e e*. The

pivotally mounted rolls can be readily adjusted to accommodate blanks of different widths. A spring-actuated presser roll *f* is arranged in front of the flanging rolls *b b*, as illustrated. A funnel-shaped former *h* is placed between the rolls *c* and *d*. As shown at fig. 132, the strip of steel as A, which is to form the core or "inside," is placed upon a wider strip of brass B, which is to form the case. According to the specification, after passing right through the machine the two strips will be delivered from the rolls *e e* (which serve not only to draw the tube through the machine but also to impart the final shape), as a cased tube such as shown at fig. 133. The patent granted on this specification has been allowed to lapse.

The specification No. 10371, of 1899, of C. Harvey, of Birmingham, describes the interposition between the casing metal and the iron or like foundation, or "inside," of soft material such as paper, wood, felt, or a soft metal alloy.

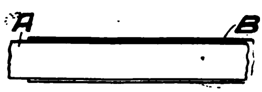


Fig. 132.

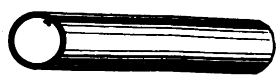


Fig. 133.

"The thin casing metal is, owing to the soft packing, not liable to sear, and sharp edges of well-defined patterns or sections may be produced in the drawn or ornamental lengths." The invention set forth in the specification No. 22668, of 1899, of the same patentee, is described as having for its object the production of "a composite tube with a brass or other ductile metal casing drawn on to a non-metallic foundation or base formed of paper, paper pulp, cardboard, wood pulp, or the like. The said foundation is fashioned and made solid by rolling or drawing, and is afterwards encased with the metal casing by drawing on a mandrel, or the foundation may be moulded."

The specification No. 2841, of 1900, of T. H. Lawton, of Birmingham, describes metal-cased tubes in which the edges of the case are secured by a jointing or locking strip. "The inner tube is placed within the case, and in drawing

ugh the circular finishing die the jointing strip is
ened within the case strip and obscured."

locking strip or clamping piece for securing the edges
he outer cases, and also of the tubular cores or
ides" of cased tubes, is described in the specification
5378, of 1897, of J. L. Wright, of Birmingham. The
nt granted on this application became void in 1901.

APPENDIX.

British Patent Specifications Relating to the Manufacture of Iron and Steel Tubes.

Note.—Where specifications have been filed as communications from abroad, the name given is that of the communicating party, *not* the formal applicant for Letters Patent.

BRAZED TUBES.

No.	Year.	Name.
5403	1826	J. T. Thompson.
13573	1851	S. Walker.
4875	1891	Earle and Bourne.
8494	1894	R. F. Hall.
20324	1895	A. Farnell.
24338	1895	Pihlfeldt and Garnett.
3955	1896	C. H. Brampton.
5771	1896	W. Starley.
10477	1896	J. V. Pugh.
10688	1896	E. Beranger and another.
22854	1896	T. Taylor.
28113	1896	F. Moore.
29800	1896	Gibbs and Wright.
29834	1896	Elkington and Fellows.
6824	1897	F. A. Wilmot.
16440	1897	Taylor and Wasdell.
20277	1898	H. Adler.
22261	1898	E. E. Ries.
7824	1899	H. Du Cros.
9198	1899	F. A. Wilmot.
10337	1899	T. Midgley.
11233	1899	A. A. Steward.
8180	1901	Jeffrey and Moxon.

BENDING, STRAIGHTENING, CORRUGATING, ETC.

4425	1877	J. Farmer. (Straightening, etc.)
4935	1877	S. Fox. (Corrugating.)

No.	Year.	Name.
4898	1878	G. Matheson. (Straightening, etc.)
2316	1882	J. Farmer. (Straightening, etc.)
2647	1882	J. Robertson. (Polishing, etc.)
840	1883	T. Drake. (Coiling.)
14469	1884	J. Wilkes. (Fluting.)
5019	1885	G. Round. (Bending.)
14993	1888	J. Shepherd. (Corrugating.)
8948	1890	G. H. Everson. (Polishing, etc.)
19040	1893	P. E. Secretan. (Corrugating.)
18731	1894	J. and G. H. McDougall. (Bending.)
20921	1894	W. B. Thompson. (Corrugating.)
11406	1895	J. and W. Pilkington. (Straightening.)
17211	1895	G. Platt. (Straightening, polishing, etc.)
18539	1895	P. Baumert. (Grooved and ribbed.)
3349	1896	S. Wilkes. (Bending.)
5078	1896	T. A. Wooldridge. (Bending.)
7221	1896	J. Rees. (Fluting or corrugating.)
8417	1896	P. Medart. (Straightening and polishing.)
13282	1896	Platts and Mather. (Twisted tubes.)
16422	1896	Young and Jones. (Corrugated cycle tubes.)
20033	1896	S. Baxter. (Corrugated cycle tubes.)
21739	1896	Shuttleworth-Browne. (Corrugated cycle tubes.)
22682	1896	S. S. Sergeant. (Corrugating.)
23873	1896	B. Wesselmann. (Corrugated cycle tubes.)
26255	1896	F. E. Elmore. (Corrugating.)
26325	1896	W. E. Gregg. (Bending.)
27703	1896	W. Webster. (Corrugated.)
11569	1897	Soc. Anonyme du Générateur du Temple. (Corrugated.)
13590	1897	J. Shaw and others. (Fluted tubes.)
19755	1897	G. Brandt. (Bending.)
351	1898	S. Frank. (Corrugating.)
3951	1898	H. Norris. (Corrugating.)
10977	1898	E. Marim. (Corrugating.)
14827	1898	C. Weber. (Bending and straightening.)
21592	1898	H. Lefèvere. (Bending.)
22962	1898	L. H. Brightman. (Straightening and polishing.)

No.	Year.	Name.
1142	1900	C. R. McKibben. (Bending.)
23827	1900	Robertson and Robertson. (Bending.)
2924	1901	J. Bradley. (Bending.)
3231	1901	F. G. Hampson. (Bending.)
16197	1901	E. J. Post. (Bending.)
16648	1901	G. Platt. (Straightening, etc.)
18272	1901	J. W. Walsh. (Corrugating.)
2432	1902	J. Earle (Bending.)
2482	1902	F. Mönkemöller. (Bending.)
11732	1902	M. Sensenschmidt. (Bending.)
26266	1902	W. W Benson. (Bending.)
576	1903	T. F. Ash. (Ornamental.)

CASED OR COMPOSITE.

(See also metal and other lined or coated tubes.)

5403	1826	J. T. Thompson.
12500	1849	J. Cutler.
2234	1854	R. W. Winfield.
1386	1884	J. Hudson.
26367	1896	H. Sheldon.
2448	1897	H. S. Whitehouse.
5378	1897	J. L. Wright.
15789	1897	Tonks Limited and Revill.
21406	1898	T. H. Lawton.
566	1899	A. P. Alvoid.
10371	1899	C. Harvey.
21699	1899	A. Schmitz.
22628	1899	A. Schmitz.
22668	1899	C. Harvey.
2841	1900	T. H. Lawton.
3711	1900	E. Madeley and others.
11035	1902	H. Knight.

CLOSE JOINT OR OPEN JOINT.

5208	1825	W. Hancock.
12500	1849	J. Cutler.
871	1857	J. J. Russell.
1769	1857	G. H. M. Muntz

No.	Year.	Name.
128	1863	Hulse and Hains.
1973	1867	G. C. Smith.
3952	1868	J. B. Clow.
2294	1869	T. F. Taylor.
2869	1870	A. Ballantyne.
3360	1870	A. and J. Stewart and another.
2542	1871	J. Huggins.
3462	1874	J. Huggins.
3577	1875	Brownhill and Smith.
3853	1875	Brownhill and Smith.
3913	1875	Brownhill and Smith.
184	1880	C. E. Smith.
446	1881	Cassels and Morton.
7034	1885	E. Dixon.
6262	1886	F. Huggins.
10149	1891	F. Huggins.
8563	1894	Broughton and Fieldhouse.
14336	1894	F. Huggins.
1484	1897	Frick and Price.
8180	1901	Jeffrey and Moxon.
12262	1901	Post, E. J.
18703	1901	J. Earle.
576	1903	T. F. Ash.

LOCK JOINT.

1415	1873	S. R. Wilmot.
1376	1878	E. Quadling.
5177	1883	Gaskell and Exton.
3187	1884	G. S. Marshall.
10640	1886	W. Allman.
19230	1891	Earle and Bourne.
7383	1896	T. S. James.
12173	1896	W. J. Goddard and others.
17581	1896	Fraser and Abrahams.
22695	1896	M. Ferguson.
7524	1897	E. J. Post.
28804	1897	M. Ferguson.
28805	1897	M. Ferguson.
21406	1898	T. H. Lawton.

No.	Year.	Name.
522	1900	T. L. Carbone.
8180	1901	Jeffrey and Moxon.
19984	1901	L. Hancox.
6493	1902	C. H. Hoskins.
7200	1902	Couston and Porritt.
14801	1902	W. H. Washington and others.

COILED OR SPIRAL STRIP.

14163	1852	W. Beasley.
839	1854	A. S. and F. S. Bolton.
2346	1854	W. Childs.
1603	1857	E. Brooks.
1352	1878	G. Paulding.
2075	1879	Stewart and Pirie.
4211	1883	G. H. Fox.
297	1884	E. Deeley.
218	1885	M. Rose.
532	1885	W. James.
5019	1885	G. Round.
8635	1886	Coas and others.
9951	1886	J. B. Root.
9952	1886	J. B. Root.
5246	1888	J. H. Breeze.
14532	1889	J. Wustenhofer.
15351	1889	W. Schroeder.
82	1892	W. Hillman.
5134	1897	A. Prim.
11311	1897	H. Ehrdardt.
11406	1898	H. Perrins. (Welded.)
10337	1899	T. Midgley.
18623	1899	E. T. Wainwright. (Welded.)
12731	1900	J. A. Crichton.
9111	1901	Kane and Taylor.
22261	1902	E. T. Greenfield.

METAL AND OTHER LINED OR COATED TUBES.

(See also cased or composite tubes.)

11377	1846	W. Palmer. (Glass lining or coating.)
12500	1849	J. Cutler.

No.	Year.	Name.
13133	1850	Everitt and Glydon.
1655	1884	T. B. Sharp.
17125	1896	E. T. Greenfield.
4478	1897	A. C. Wright.
29006	1897	A. E. Hills.
30357	1897	H. Lamoisse. (Celluloid coating.)
8394	1898	H. W. Davies. (Lead coating).
18969	1898	E. J. Braddock.
23179	1898	H. W. Davies.
5977	1899	S. S. Walker.
9057	1899	E. J. M. La Combe. (Silver coating.)
10294	1899	Hinds and Lewis.
13844	1899	G. H. Everson.
874	1900	L. G. Bandelot.
10006	1900	S. E. Howell.
11981	1900	Beck and Townsend.
22791	1900	J. A. Crane.
3292	1902	J. Reynolds.
7886	1902	W. Greaves.

TAPER.

3740	1813	H. Osborne.
2181	1853	F. Potts.
1343	1854	Reeves and Wells.
3066	1861	Russell and Brown.
541	1864	G. P. Harding.
3156	1870	H. Kesterton.
1140	1874	Hoskins and Harvey.
1449	1876	T Rickett.
6100	1885	Hughes, Johnson, and Blakemore.
15308	1885	H. Waters.
13357	1888	W. Pilkington.
1598	1889	W. Lorenz.
13396	1889	W. H. Butler.
17090	1892	Pilkington and others.
19176	1892	Pilkington and others.
8205	1894	Faulkner and others.
22733	1894	Faulkner and others.
6780	1895	Deutsche metallpatronenfabrik.

No.	Year.	Name.
17032	1896	A. H. Hüsener.
21865	1896	H. O. Harris.
3597	1897	F. J. Seyfried.
3911	1898	Lones and Holden.
2666	1899	H. J. Waddie.
3157	1899	E. Bock.
5985	1899	T. B. Sharp.
5355	1901	A. M. Reynolds.
7877	1901	W. Schwiethal.
9888	1901	E. Bock.
21180	1902	A. Mauser.

BUTTED OR VARYING THICKNESS.

11095	1891	Taylor and Challen.
21822	1893	C. L. Stiff.
9803	1894	Clarendon Tube Co. and another.
10803	1897	E. Ivins.
18121	1897	A. E. Beck.
18307	1897	T. B. Sharp.
24931	1897	Reynolds and Hewitt.
27200	1897	B. Rose.
28160	1897	S. E. Howell.
30451	1897	R. C. Stiefel.
27215	1898	H. J. Brookes and others.
8749	1901	T. B. Sharp.

D AND OVAL SECTIONS.

8205	1894	Faulkner and others.
13137	1896	Ames and Stokes.
17549	1896	F. A. Walton.
22758	1896	C. T. B. Sangster.
22854	1896	T. Taylor.
13843	1897	New Brotherton Tube Co. and others.

WELDED.

3590	1812	H. Osborn.
3617	1812	H. Osborn.
4105	1817	H. Osborn.
4191	1817	J. F. Chabannes.

No.	Year.	Name.
4892	1824	J. J. Russell.
5109	1825	C. Whitehouse.
6097	1831	G. Royle.
6995	1836	Harvey and Brown.
7081	1836	T. H. Russell.
8454	1840	R. Prosser.
9140	1841	J. Cutler.
9287	1842	Russell and Whitehouse.
9723	1843	J. Roose.
10122	1844	J. Hardy.
10272	1844	J. J. and T. H. Russell.
10380	1844	J. Hardy.
10546	1845	J. Selby.
10621	1845	G. Royle.
10649	1845	R. Prosser.
10696	1845	C. Whitehouse.
10710	1845	J. Hardy.
10816	1845	T. H. Russell.
11197	1846	W. Church.
11360	1846	J. Roose.
12021	1848	Cutler and Robinson.
12158	1848	W. Taylor.
12918	1850	Cochrane and Slate.
13035	1850	R. Prosser.
13130	1850	T. Deakin.
586	1852	G. F. Selby.
819	1852	J. Roose.
3017	1853	A. F. Remond.
2527	1855	T. Pritchard.
1223	1856	J. Cutler.
1610	1856	A. Herts.
2251	1856	Russell and Howell.
2827p.p.	1856	L. W. Wright.
72	1857	Russell and Howell.
2685	1858	S. Oram.
2765p.p.	1858	S. Peters.
329	1860	E. Lea.
1552	1860	J. E. Barnsley.
2941	1860	E. T. Hughes.

No.	Year.	Name.
52	1862	Jessen and others.
1146	1862	W. Rose.
2626	1862	E. Dixon.
1858	1865	S. Hingley.
1868	1866	G. Plant.
1937	1867	Galloway and Plant.
2713	1868	J. Evans.
3209	1869	G. Northall.
1435	1870	E. Peyton.
1571	1870	R. Briggs.
1799	1870	A. and J. Stewart.
3391	1870	S. P. M. Tasker.
3440	1873	J. Fairbanks. (Hollow pile.)
1024	1874	J. Evans.
3415	1874	G. H. M. Muntz.
209	1875	J. C. Johnson.
290	1875	H. Bristow.
1562	1875	T. P. Allen.
2765	1875	H. Kesterton.
10	1876	T. P. Allen.
756p.p.	1876	R. A. Malcolm.
2152	1876	E. Deeley.
1202	1877	Peyton and Bourne.
2906p.p.	1877	E. Roden.
30	1878	J. McDougall.
4946	1878	McKenzie and Perkins.
4964	1878	Selby and Garter.
514	1879	W. Brawnhill.
4022	1879	A. and J. Stewart and another.
184	1880	C. E. Smith.
1254	1880	J. Hooven.
446	1881	Cassels and Morton.
1806	1881	H. von Hartz and O. Fix.
2998	1881	A. A. Murphy. (Hollow pile.)
3041	1881	A. A. Murphy. (Hollow pile.)
1005	1882	W. H. Wood.
2157	1883	E. Quadling.
3152	1884	J. Pumphery.
16689	1884	Jones and Smith.

No.	Year.	Name.
3344	1885	E. Dixon.
7034	1885	E. Dixon.
13628	1885	J. A. Crane.
5641	1890	H. Howard.
11374	1890	W. R. Comings.
20478	1890	W. Brownhill.
1208	1891	J. H. Bevington.
3706	1891	D. Muckley.
4655	1891	W. Brownhill.
5808	1891	Wotherspoon and others.
17250	1892	J. E. and H. Howard.
18007	1892	R. Hutton.
15119	1893	A. H. Williams.
16542	1893	Babcock and Wilcox.
16543	1893	Babcock and Wilcox.
19289	1893	W. Allman and E. Deeley.
10948	1894	J. P. Serve.
30544	1897	O. Parpart. (Electric welding.)
22947	1897	H. Perrins. (Direct from piled bars.)
3332	1898	A. Pilkington.
17986	1898	C. Twer.
19059	1898	Minton and Brookes.
22261	1898	E. E. Ries.
22447	1898	C. Puff.
4312	1899	G. T. Thompson. (Electric Welding Manufacturing Company.)
4410	1899	Vanstone and McGuinness.
7116	1899	T. J. Bray. (Bench.)
7117	1899	T. J. Bray.
9662	1899	Rushton and Baldwin.
16550	1899	E. Johnson.
16755	1899	H. Perrins.
21699	1899	A. Schmitz.
22685	1899	A. Pilkington. (Iron and steel.)
4996	1900	J. C. Nickling. (Pile.)
5867	1900	H. Perrins.
8966	1900	A. L. Murphy.
18386	1900	F. Billing and others.
3830	1901	H. Perrins.

No.	Year.	Name.
10708	1901	H. Perrins.
18937	1901	C. Twer.
1006	1902	T. F. Rowland.
2331	1902	F. J. T. Haskew.
3234	1902	T. K. Barclay.
26540	1902	National Tube Company.
27481	1902	B. Kronenberg.

SEAMLESS OR WELDLESS.

8536	1840	A. S. Stocker. (Hollow ingot of malleable cast iron.)
12334	1848	J. O. York. (Hollow cast steel ingots.)
13037	1850	E. A. Chameroy. (Tubular billets of iron.)
472	1854	J. D. M. Stirling. (Cast steel tubular ingots.)
688	1854	J. Newman. (Wrought iron hollow billets.)
1023	1863	J. Thompson. (Tubular billets.)
441	1874	E. P. Wilbur. (Rolling tube from solid ingot.)
1467	1888	C. A. Marshall. (Ingot with yielding core.)
8948	1890	G. H. Everson. (Polishing, etc.)
4358	1892	La Campagnie Francaise des Metraux. (Ribbed.)
4794	1893	B. and G. Shorthouse. (Hollow billets.)
7643	1895	C. G. P. de Laval. (Hollow billets.)
23628	1900	H. J. Brookes. (Hollow billets.)

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2009	1878	E. Quadling. (Direct from molten or plastic metal.)
846	1882	R. Elliott. (Direct from molten or plastic metal.)
1590	1889	W. E. Koch. (Direct from molten or plastic metal.)
19153	1890	Morton and Adcock. (Direct from molten or plastic metal.)
15912	1891	Lane and Chamberlain. (Direct from molten or plastic metal)

No.	Year.	Name.
14078	1894	A. F. E. Dupont. (Direct from molten or plastic metal.)
22748	1894	A. F. E. Dupont. (Direct from molten or plastic metal.)
10475	1897	G. H. Clowes. (Direct from molten or plastic metal.)

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13534	1851	A. F. Redmond.	(Drawn blanks or discs.)
5597	1882	S. Walker.	,,
2552	1884	S. Fox.	,,
5265	1885	W. H. Brown.	,,
10315	1885	W. H. Brown.	,,
18386	1890	Pilkington and others.	,,
11095	1891	Taylor and Challen.	,,
20364	1891	Cayley and Courtman.	,,
12144	1892	G. Hookham.	,,
1270	1893	B. Hewitt.	,,
8438	1900	F. Deeming.	,,

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1018	1864	J. Thompson.	(Piercing solid billets.)
15752	1884	J. Robertson.	,,
1167	1885	R. and M. Mannesmann.	,,
9939	1886	R. and M. Mannesmann.	,,
666	1887	R. and M. Mannesmann.	,,
6453	1887	R. and M. Mannesmann.	,,
5018	1888	J. Robertson.	,,
14799	1888	Pilkington and others.	,,
1627	1890	J. Robertson.	,,
3116	1891	H. Ehrhardt.	,,
11436	1891	J. Robertson.	,,
7497	1892	H. Ehrhardt.	,,
24	1893	Wüstenhöfer and Surmann	,,
533	1893	P. Hesse.	,,
14352	1893	Wüstenhöfer and Surmann	,,
23702	1895	R. Stiefel.	,,
1064	1896	R. Bungeroth.	,,
3054	1896	J. Robertson.	,,
14801	1896	E. Hollings.	,,

No.	Year.	Name.	
17470	1896	W. & A. Pilkington.	(Piercing solid billet
17950	1896	W. and A. Pilkington.	,,
21177	1896	P. Hesse.	,,
22806	1896	J. L. B. Templer.	,,
10647	1897	J. A. Hampton.	,,
13386	1897	Sharp and Billing.	,,
14001	1897	J. A. Charnock.	,,
14562	1897	Sharp and Billing.	,,
29105	1897	Tannahill and Eadie.	,,
30358	1897	E. L. Cooper.	,,
30449	1897	R. C. Stiefel.	,,
611	1898	R. C. Stiefel.	,,
8148	1898	J. C. Sturgeon.	,,
9144	1898	W. Pilkington.	,,
932	1899	J. A. Hampton.	,,
7963	1899	E. Pilkington.	,,
12828	1899	L. D. Davis.	,,
15772	1899	E. L. Cooper.	,,
21237	1899	Hernadthaler Ungarische Eisenindustrie Actiengesellschaft.	,,
3329	1900	T. Ledermüller.	,,
1691	1901	S. E. Diescher.	
4312	1901	C. de Los Rice.	,,
10878	1901	Evans and Tubes Ltd.	
15317	1901	A. Pilkington.	,,
17326	1901	H. R. Keithley.	,,
1716	1902	B. F. McTear.	,,
3162	1902	G. Gleichmann.	
4132	1902	F. D. Everitt.	,,
7781	1902	Joseph and Tubes Ltd.	,,

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748	1852	J. Dumery.	(Rolling.)
2533	1861	Christoph and others.	,,
2614	1861	Bourne and Kidd.	,,
1525	1862	E. Fewtrell.	,,
3251	1864	W. H. Brown.	,,
3289	1865	T. Rickett.	,,

No.	Year.	Name.		
538 ...	1866 ...	W. Webb.	(Rolling.)	
3333 ...	1867 ...	W. F. Brooks.	,,	
1980 ...	1870 ...	H. Kesterton.	,,	
657 ...	1878 ...	Waldenstrom and Sumner.	,,	
2939 ...	1878 ...	J. G. Williams.	,,	
3928 ...	1878 ...	A. Clifford.	,,	
4201 ...	1878 ...	J. Robertson.	,,	
35 ...	1879 ...	S. Fox.	,,	
752 ...	1879 ...	S. Fox.	,,	
1566 ...	1879 ...	G. Whitehead.	,,	
371 ...	1880 ...	J. Atkinson.	,,	
5202 ...	1882 ...	G. Little.	,,	
1033 ...	1883 ...	P. M. Parsons.	,,	
2844 ...	1883 ...	C. Kellogg.	,,	
7462 ...	1884 ...	F. Johnson.		
5754 ...	1885 ...	T. R. Bayliss.	,,	
9537 ...	1885 ...	C. Kellogg.	,,	
6453 ...	1887 ...	R. and M. Mannesmann.	,,	
10796 ...	1887 ...	Cope and Hollings.	,,	
12042 ...	1887 ...	C. Kellogg.	,,	
13760 ...	1887 ...	C. White.	,,	
14515 ...	1887 ...	M. Gledhill.	,,	
14532 ...	1887 ...	M. Gledhill.	,,	
5018 ...	1888 ...	J. Robertson.	,,	
6493 ...	1888 ...	S. T. M. Tasker.	,,	
6494 ...	1888 ...	S. T. M. Tasker.	,,	
9754 ...	1888 ...	R. Mannesmann.	,,	
14278 ...	1888 ...	Pilkington and others	,,	
18477 ...	1888 ...	W. H. Appleton.	,,	
2933 ...	1889 ...	C. Kellogg.	,,	
8496 ...	1889 ...	Faulkner and Lloyd	,,	
16934 ...	1889 ...	Pilkington and others	,,	
11047 ...	1890 ...	E. F. Randolph.	,,	
16990 ...	1890 ...	C. Kellogg.	,,	
17162 ...	1890 ...	W. Heckert.	,,	
3771 ...	1891 ...	M. Mannesmann.	,,	Pilger
4050 ...	1891 ...	M. Mannesmann.	,,	Pilger
15265 ...	1891 ...	A. Mathies.	,,	
4595 ...	1892 ...	R. Mannesmann.	,,	

No.	Year.	Name.		
7135 ...	1892 ...	R. Mannesmann	(Rolling.)	
12473 ...	1892 ...	G. Hatton.	„	
12482 ...	1892 ...	Cope and Hollings.	„	
533 ...	1893 ...	P. Hesse.	„	
1548 ...	1893 ...	B. Butterworth.	„	
9657 ...	1893 ...	Pilkington and others.	„	
13878 ...	1893 ...	W. Holland.	„	
15261 ...	1893 ...	E. Martin.	„	
3038 ...	1894 ...	F. O. and W. Schulte.	„	
7332 ...	1894 ...	C. G. Larson.	„	
18958 ...	1894 ...	R. F. Hall.	„	
20690 ...	1894 ...	P. Hesse.	„	
3176 ...	1895 ...	F. O. and W. Schulte.	„	
7852 ...	1895 ...	Pilkington and others.	„	
9696 ...	1895 ...	Pilkington and others.	„	
11787 ...	1895 ...	P. Hesse.	„	
13092 ..	1895 ...	Pilkington and others.	„	
22979 ...	1895 ...	Pilkington and others.	„	
13746 ...	1895 ...	R. and M. Mannesmann.	„	
14249 ...	1895 ...	R. and M. Mannesmann.	„	Pilg
16486 ...	1895 ...	R. and M. Mannesmann.	„	Pilg
18255 ...	1895 ...	C. G. Larson.	„	
22979 ...	1895 ...	Pilkington and others.	„	
854 ...	1896 ...	H. Ehrhardt.	„	
3683 ...	1896 ...	M. Mannesmann.	„	Pilg
6571 ...	1896 ...	R. and M. Mannesmann.	„	Pilg
11775 ...	1896 ...	J. Davis.	„	
15895 ...	1896 ...	C. T. B. Sangster.	„	
21177 ...	1896 ...	P. Hesse.	„	
22770 ...	1866 ...	J. Wotherspoon.	„	Pilg
27488 ...	1896 ...	Hamilton and Miller.	„	
9880 ...	1897 ...	W. Pilkington.	„	Pilg
9917 ...	1897 ...	Price and others	„	Pilg
11311 ...	1897 ...	H. Ehrhardt.	„	
14070 ...	1987 ...	J. Wotherspoon.	„	Pilg
14186 ...	1897 ...	W. and A. Pilkington	„	Pilg
30450 ...	1897 ...	R. C. Stiefel.	„	
612 ...	1898 ...	R. C. Stiefel.	„	
3911 ...	1898 ...	Lones and Holden.	„	Pilg

No.	Year.	Name.		
7787 ...	1898 ...	Tannahill and Eadie.	(Rolling.)	
21744 ...	1898 ...	Lones and Holden.	„	Pilger.
25122 ...	1898 ...	McTear and Lindsay.	„	
25580 ...	1898 ...	O. Klatte.	„	
7963 ...	1899 ...	E. Pilkington.	„	
12747 ...	1899 ...	H. Ehrhardt.	„	
12828 ...	1899 ...	L. D. Davis.	„	
15072 ...	1899 ...	O. Klatte.	„	
17473 ...	1899 ...	H. R. Keithley.	„	
19087 ...	1899 ...	B. F. McTear.	„	
23365 ...	1899 ...	B. F. McTear.	„	
23741 ...	1899 ...	O. Klatte.	„	
25636 ...	1899 ...	J. Gieshoidt.	„	
3329 ...	1900 ...	T. Ledermüller.	„	
3580 ...	1900 ...	Aston and Holland.	„	
3788 ...	1900 ...	G. Beesly.	„	
5425 ...	1900 ...	H. Perrins.	„	Pilger.
5927 ...	1900 ...	A. E. Beck.	„	Pilger.
7315 ...	1900 ...	H. Perrins.	„	Pilger.
12203 ...	1900 ...	A. E. Beck.	„	Pilger.
13981 ...	1900 ...	Laybourne and Marsh.	„	Pilger.
14416 ...	1900 ...	O. Heer.	„	Pilger.
92 ...	1901 ...	R. C. Stiefel.	„	Pilger.
1481 ...	1901 ...	J. Gieshoidt.	„	
2590 ...	1901 ...	Bartlett and Kent.	„	
6639 ...	1901 ...	R. C. Stiefel.	„	
13291 ...	1901 ...	J. Reimann.	„	Pilger.
13519 ...	1901 ...	B. F. McTear.	„	
14384 ...	1901 ...	Chamberlain and Tubes Ld.	„	
14615 ...	1901 ...	B. F. McTear.	„	
16385 ...	1901 ...	O. Briede.	„	Pilger.
21533 ...	1901 ...	J. Gieshoidt.	„	
21570 ...	1901 ...	J. A. Hampton.	„	Pilger.
23455 ...	1901 ...	A. E. Beck.	„	Pilger.
23992 ...	1901 ...	R. C. Stiefel.	„	
25307 ...	1901 ...	R. Mengelbeir.	„	
3372 ...	1902 ...	La Société Vogt et Cie.	„	
4553 ...	1902 ...	M. Mannesmann.	„	
4554 ...	1902 ...	M. Mannesmann.	„	

No.	Year.	Name.		
4625 ...	1902 ...	M. Mannesmann.	(Rolling.)	
4626 ...	1902 ...	M. Mannesmann.	,,	
4627 ...	1902 ...	M. Mannesmann.	,,	
4628 ...	1902 ...	M. Mannesmann.	,,	
4629 ...	1902 ...	M. Mannesmann.	,,	
4956 ...	1902 ...	J. A. Hampton.	,,	Pilge
20207 ...	1902 ...	Stirling Co.	,,	
21636 ...	1902 ...	J. Sandner.	,,	

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748 ...	1852 ...	C. J. Dumery.	(Drawing.)	
3090 ...	1856 ...	Speed and Bailey.	,,	
2533 ...	1861 ...	Christoph and others.	,,	
3262 ...	1862 ...	Christoph and others.	,,	
1462 ...	1866 ...	Gibson and Ellis.	,,	
3333 ...	1867 ...	W. F. Brooks.	,,	
2511 ...	1877 ...	W. C. Stiff.	,,	
4201 ...	1878 ...	J. Robertson.	,,	
4022 ...	1879 ...	Stewart and others.	,,	
1929 ...	1882 ...	W. Randle.	,,	
491 ...	1883 ...	T. B. Sharp.	,,	
5876 ...	1883 ...	C. C. Billings.	,,	
9560 ...	1884 ...	J. Short.	,,	
15752 ...	1884 ...	J. Robertson.	,,	
12823 ...	1885 ...	Stiff and Bennett.	,,	
5268 ...	1887 ...	W. von Flotow and H. Leidig.	,,	
12766 ...	1887 ...	V. J. Feeney.	,,	
5018 ...	1888 ...	J. Robertson.	,,	
12624 ...	1888 ...	W. Lorenz.	,,	(Releasing.
3519 ...	1893 ...	W. and J. Crawford.	,,	
9657 ...	1893 ...	Pilkington and others.	,,	,,
19356 ...	1893 ...	J. Robertson.	,,	
12012 ...	1894 ...	Wootton and Hewitt.	,,	,,
12270 ...	1894 ...	Wootton and Gould.	,,	,,
2474 ...	1895 ...	J. Hudson.	,,	,,
5389 ...	1895 ...	Wootton and Hewitt.	,,	,,
5478 ...	1895 ...	R. Wootton.	,,	,,
9696 ...	1895 ...	Pilkington and others.	,,	,,

also reducing

No.	Year.	Name.		
17208 ...	1895 ...	Pilkington and others.	(Drawing and Releasing.)	
17211 ...	1895 ...	G. Platt.	"	"
530 ...	1896 ...	Pilkington and others.	"	"
4569 ...	1896 ...	G. Platt.	"	
6149 ...	1896 ...	W. and A. Pilkington.	"	"
8277 ...	1896 ...	J. Hudson.	"	"
11260 ...	1896 ...	R. F. Hall and others.	"	"
25686 ...	1896 ...	W. A. McCool.		
1192 ...	1897 ...	A. Smallwood.	"	
6270 ...	1897 ...	J. Robertson.	"	
10539 ...	1897 ...	A. C. Wright.	"	
17157 ...	1897 ...	A. C. Wright.	"	
23400 ...	1897 ...	A. Smallwood.	"	
24266 ...	1897 ...	P. E. Secrétan.	"	
28699 ...	1897 ...	E. Ivins.	"	"
4897 ...	1898 ...	W. A. McCool.	"	
12188 ...	1898 ...	H. Ehrhardt.	"	
4443 ...	1899 ...	A. M. Reynolds.	"	
12747 ...	1899 ...	H. Ehrhardt.	"	
14854 ...	1899 ...	J. L. Kempson.	"	
15419 ...	1899 ...	G. Muntz.	"	
17473 ...	1899 ...	H. R. Keithley.	"	
6640 ...	1901 ...	Stiefel and Brown.	"	
8749 ...	1901 ...	T. B. Sharp.	"	
16582 ...	1901 ...	B. F. McTear.	"	
18041 ...	1901 ...	Hudson Bros. and Knight.	"	
5752 ...	1902 ...	W. Sumner.	"	

SWAGING, DRIFTING, AND OTHER TUBE-MAKING OPERATIONS AND MACHINES.

9200 ...	1885 ...	S. Fox.
3038 ...	1886 ...	Babcock and Wilcox.
3039 ...	1886 ...	Babcock and Wilcox.
4039 ...	1891 ...	G. Hookham.
13935 ...	1891 ...	J. P. Kennedy.
20467 ...	1897 ...	G. J. Capewell.
16043 ...	1899 ...	A. E. Beck.
20943 ...	1899 ...	H. A. Eckstein.

No.	Year.	Name.
1679	... 1901 ...	Lones and Holden.
4312	... 1901 ...	C. de Los Rice.
12927	... 1901 ...	Stirling Co.
12928	... 1901 ...	Stirling Co.
12949	... 1901 ...	Stirling Co.
12952	... 1901 ...	Stirling Co.
22969	... 1901 ...	Stirling Co.

STRENGTHENING, THICKENING, AND STAVING, ETC.

5573	... 1827 ...	R. W. Winfield. (Wood filling.)
565	... 1854 ...	W. B. Johnson. (Staving.)
901	... 1866 ...	Deakin and Johnson. (Swaging, etc.)
4574	... 1896 ...	Smillie and Bird. (Coiled wire or tape.)
4702	... 1896 ...	A. Kirschbaum. (Cork filling.)
344	... 1897 ...	T. N. Waller. (Staving.)
14530	... 1898 ...	J. R. Blakeslee. (Staving.)
12206	... 1901 ...	P. Fowler. (Strengthening by air under pressure.)

MISCELLANEOUS.

560	... 1853 ...	R. A. Brooman. (Roller dies.)
1680	... 1855 ...	R. A. Brooman. (Roller dies.)
1105	... 1856 ...	R. A. Brooman. (Segmental dies.)
1570	... 1870 ...	R. Briggs. (Operating die tongs.)
4361	... 1880 ...	J. C. Johnson. (T pieces, etc.)
170	... 1881 ...	W. H. Brown. (Combined reeling and rolling.)
2998	... 1881 ...	A. L. Murphy. (Tubes from puddled iron.)
3041	... 1881 ...	A. L. Murphy. (Tubes from puddled iron.)
3060	... 1881 ...	W. H. Brown. (Combined reeling and rolling.)
1771	... 1882 ...	Fox and Whitley. (Furnaces.)
1033	... 1883 ...	P. M. Parsons. (Rotating mandrels.)
9560	... 1884 ...	J. Short. (Rotating dies.)
5436	... 1887 ...	J. P. Serve. (Ribs.)
7709	... 1888 ...	J. P. Serve. (Ribs.)
15059	... 1888 ...	W. Lorenz. (Internal partition.)
10470	... 1889 ...	J. P. Serve. (Internal ribs.)
176	... 1890 ...	H. Moerchen. (Filling before drawing.)

No	Year.	Name.
8152	1890	C. Kellogg. (Mandrels.)
8948	1890	G. H. Everson. (Polishing, etc.)
3122	1891	J. G. Bohl. (Revolving die.)
16811	1891	G. Hookham. (Revolving die.)
4358	1892	La Compagnie Française des Metaux. (Ribbed.)
6884	1893	C. G. Larson. (Ribs.)
15927	1893	Stewart and Clydesdale. (Mandrels.)
6697	1894	J. Ritchie. (Internal ribs.)
8320	1894	A. Dumas. (Internal ribs.)
13095	1894	C. Wilmott. (Ornamenting.)
4493	1896	C. E. Smith. (Mandrels.)
11950	1896	H. Loesner. (Twisted or interlaced wire and molten metal.)
12389	1896	J. Aylward. (Special form of cycle tubing.)
15896	1896	C. T. B. Sangster. (Tagging, etc.)
21175	1896	R. S. Lovelace. (Tempering or toughening.)
27405	1896	T. Key. (Riveted tubes for cycles.)
4890	1897	W. Hillman. (Sheet metal cycle tubes.)
8466	1897	E. Taylor. (Riveted tubes for cycles.)
21804	1897	W. E. Partridge. (Moulding cycle tubing.)
11500	1898	Safety Conduit Co. (Cleaning tubes.)
16668	1898	E. Gearing. (Welding furnaces.)
1581	1899	E. F. G. Pein. (Enamelling tubes.)
8226	1899	H. Walters. (Furnace.)
9660	1899	E. Ehrhardt. (Gun barrels.)
10184	1899	E. Jones. (Tubes for roller bearings.)
24959	1899	A. Schmitz. (Internally ribbed compound pipes.)
1309	1900	J. Earle. (Compound tube.)
7417	1900	A. Schmitz. (Tubes with internal partition.)
19621	1900	H. Perrins. (Internally ribbed tube.)
2934	1901	F. Stordeur. (Internal examination.)
12928	1901	Stirling Co. (Mandrel for forming boiler headers, etc.)
17319	1901	J. E. Goldschmid. (Heating furnace for tubes.)
1413	1903	F. Reissner. (Metallic poles for electric railways, etc.)

INDEX.

JOHN HEYWOOD, Excelsior Printing and Bookbinding Works Manchester.